23rd ONTARIO INDUSTRIAL WASTE CONFERENCE

JUNE 13-16, 1976
TORONTO, ONTARIO

PROCEEDINGS

Ministry
of the
Environment
Ontario

The Honourable
George A. Kerr, Q.C.,
Minister

Everett Biggs,
Deputy Minister

23rd Ontario waste
management conference :
proceedings /

P R O C E E D I N G S

O F T H E

T W E N T Y - T H I R D
O N T A R I O I N D U S T R I A L
W A S T E C O N F E R E N C E

H E L D A T
THE PRINCE HOTEL, TORONTO

JUNE 13 - 16, 1976

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PREFACE TO THE

PROCEEDINGS OF THE TWENTY-THIRD

ONTARIO INDUSTRIAL WASTE CONFERENCE

K. H. SHARPE
Assistant Deputy Minister
Environmental Assessment & Planning
Ministry of the Environment
and
Chairman
Ontario Industrial Waste
Conference Planning Committee

When you start assembling the papers for the printing and distribution of the proceedings of a conference, you know your assignment for the year is about over. I am pleased to present to you the Proceedings of the 23rd Ontario Industrial Waste Conference which was held in Toronto in June 1976. I hope it will be a lasting record of this most successful undertaking.

In the past, we have received complaints from delegates, and others, about the length of time that elapses from the end of our Conferences and the issuing of the Proceedings. Usually it's four or five months, and sometimes even longer. For the benefit of those who don't know, all of the organization, planning, execution and production of the Proceedings is done by "volunteer" members of the Planning Committee. They stage and orchestrate the Conference in their spare time, with their very stringent and demanding responsibilities relating to the environmental protection of the Province of Ontario taking precedent in every instance. Production, printing and distribution of the Proceedings is the last major activity of the total Conference package.

If you eliminate the summer holiday months, because of the unavailability of staff, and the procurement of papers from the speakers for the same reason, your production time is cut considerably.

Then there's the retyping required, the layout and assembly, printing, addressing and distribution, which actually takes about three months of volunteer time. All considered, it's not too long when our number one rule is to have the Proceedings complete and accurate. If there is a delay, it is usually because we cannot meet the standard we have set for ourselves in the interest of the delegate attending the Ontario Industrial Waste Conference. After all, the Proceedings is part of the registration package, and must be right.

The 1976 Ontario Industrial Waste Conference was the most successful ever, passing the 1975 Conference by a considerable margin in attendance. Five hundred and fifty-two people registered for the Conference -- the largest number we have ever had. This was comprised of 432 delegates, 27 program participants, 78 delegate spouses, six media representatives and nine committee members and staff. The success of the 1976 Conference can be directly attributed to the high calibre of papers that were presented, the smooth flow of the proceedings because of the capabilities of the session chairmen, and the preliminary planning and execution that was undertaken by the Conference Planning Committee and the Technical Program Committee.

And as the Ontario Industrial Waste Conference continues to grow, it also continues to be national and international in content and attendance. This year eight of Canada's 10 provinces were represented by delegates, and there were 11 delegates present from the United States. The international flavour and reputation of the OIWC has been borne out by a Guest Editorial which appeared in the August issue of Water and Pollution Control. Accolades of this nature are few and far between, so we couldn't resist reprinting the editorial in this issue of the Proceedings. We much appreciate the comments of the author.

I have had the pleasure of chairing the Ontario Industrial Waste Conference for the past three years. Its success is dependent on good organization and execution. I would like to give full credit to the Conference Planning Committee and its members for achieving this objective not only in 1976, but also in the other years that I have been associated with the Conferences. Without these dedicated

"volunteers," there probably wouldn't be a conference nor would it be as successful. I appreciate their work, co-operation and support.

For your information the 24th Ontario Industrial Conference will again be held at the Prince Hotel in Toronto in 1977. The dates will be May 29 to June 1 inclusive. We've advanced the dates purposefully so the OIWC will not conflict with other environmental meetings that are scheduled for Toronto later in the month. I hope that all delegates who attended the 1976 Conference will return for our 1977 proceedings.

K.N. Sharpe.
Conference Chairman

1976 ONTARIO INDUSTRIAL WASTE CONFERENCE PLANNING COMMITTEE




M.F. CHEETHAM Conference Co-ordinator	J.B. PATTERSON Program Convener	D.P. CAPLICE Committee Member	E.W. TURNER Committee Member

1976 OIWC TECHNICAL PROGRAM COMMITTEE

T.D. Armstrong Manager Industrial Abatement - Central Region	E.T. Barrow Head New Technology - Air Resources	G.C. Chisamore Manager Program Development - Resource Recovery
W.J. Hogg Head Mining & Metallurgy - Pollution Control	R.C. Stewart Manager Technical Support - West Central Region	

OPENING REMARKS

by

THE HONOURABLE GEORGE A. KERR, Q.C.
MINISTER OF THE ENVIRONMENT
PROVINCE OF ONTARIO

The Honourable George A. Kerr, Q.C., was appointed Minister of the Environment on October 7, 1975.

In a previous term he was Ontario's first Environment Minister when he was appointed Miniser of the Department of Energy and Resources Management in June, 1969. In 1972, this Department, through additions and alterations, became the Department of the Environment.

Since 1972, Mr. Kerr has held the Cabinet positions of Minister of the Department of Colleges and Universities (appointed February 1972); Provincial Secretary for Justice (appointed September 1972) and Solicitor-General (appointed February 1975).

Mr. Kerr has served in the Ontario Legislature representing Halton from 1963 until 1975 when he was elected to represent the new riding of Burlington South.

He has served on a number of government committees including the Standing Committee on Municipal Affairs, the Select Committee dealing with Consumer Credit, and the Select Committee on Conservation Authorities and Water Resources. Before entering provincial service, Mr. Kerr was a member of the Burlington Town Council in 1955/56 and 1962/63.

Mr. Kerr was called to the Ontario Bar in 1955. In 1967 he was named Queen's Counsel.

OPENING REMARKS

By:

The Honourable George A. Kerr, Q.C.

Thanks, Ken, for the introduction. I noticed that you used that old cliche "Somebody who really doesn't need an introduction." As a politician, I hope that's true, but as the Ontario Minister of the Environment, there are those around this province that really do not want to be introduced to me -- like the canners, the pulp and paper makers, the PCB-users and a few others.

This portfolio doesn't always endear oneself to his business associates -- but it's a job that has to be done if we are to preserve the environment of Ontario for today's and tomorrow's citizens. That's one of the reasons why we are here for the next three days.

The 23rd Ontario Industrial Waste Conference. Time certainly flies. I remember when I was in this portfolio in the Late 60s, making the trip over to Niagara Falls to attend some of the sessions. Dave Caverly was the conference chairman then. He originated the idea and chaired them until he moved over as chairman of what is now the Environmetnal Assessment Board. Ken Sharpe has been the Chairman for the last two conferences and my congratulations to him and his committee for carrying on the tradition in such a commendable fashion.

It's not easy to stage 23 consecutive conferences, vary the program sufficiently to make it continually appealing, and choose a location that will be conductive to Environmental thinking. From the size of this audience, the advanced registration, and the interest and intent on your faces, I would speculate that the 1976 conference will be as successful as ever, and probably surpass last year's record registration. Let's hope so anyway.

In the 50s and 60s, the theme of the Ontario Industrial Waste Conference concentrated on water management and pollution control. Since 1972, when the Ministry of the Environment was formed, we've broadened our scope, introduced air and solid waste management, and this year we are raising our sights even higher with the introduction of the multiple aspects of Environmental Assessment.

My Deputy Minister Everett Biggs, unfortunately is on business in Northern Ontario and Dennis Caplice will be the first speaker on the formal program discussing Environmental Assessment, what it is and how it's going to work. He'll be followed by Dr. R. Logie, Chairman of Environment Canada's Environmental Assessment Panel, and Clifford Lax, a fellow member of the bar. Between the three of them you should have a good overview of Environmental Assessment, how it's going and whether or not it really will be the nightmare which certain critics suspect.

x

I won't delve into this subject any further because I do not want to upstage the members of the panel who are about to follow. All I would like to say is that, in my opinion, the Environmental Assessment Act of the Province of Ontario is one of the most important pieces of legislation that we have introduced in this Province. It is designed to protect and improve the quality of the human as well as the natural environment.

Last year E. Biggs spoke on the new Ministry of the Environment, covering its re-organization and decentralization. Those of you who deal on a regular basis with our Ministry should be able to get quicker response to our queries because of our Regional Office structure. The new concept is going quite well. Never before have we been more accessible and responsive to the general public and our clients.

Regional Directors and their staffs are in the field to serve our customers, and to oversee the protection of the Environment. Colin MacFarlane, the Director from the West Central Region, will be chairing the session this afternoon; and Paul Cockburn, our Central Region Director, will be the session chairman tomorrow morning. Those of you from the Hamilton or Metropolitan Toronto areas should make yourself acquainted with Colin and Paul -- they are your Environmental contacts in these areas.

We also have regional offices in Kingston, Thunder Bay, Sudbury and London. Some of the Directors from those areas are also here at the conference. Meet them and use our Regional Ministry facilities to help solve your Environmental problems.

Earlier I commented on the development of the program for one of these conferences. I said it wasn't easy to vary it every year so that it would continue to be appealing and productive. This year was no different. To aid us in the selection of papers for presentation, we try and solicit those that have direct or indirect Environmental overtones.

I think the Technical Program Committee, under the convenorship of John Patterson, did an excellent job this year. For example, Dr. Carole Burnham, a Toronto Consultant, will discuss the conversion of wood wastes to energy in a central facility in the Northern Ontario, Town of Hearst.

Here's a situation where we are solving a smoke and odour pollution problem from the burning of wood wastes in teepee burners and at the same time providing an energy source for the community at savings over the price currently being paid for power.

Dust control from 300 million bushels of grain handled in the Thunder Bay terminal elevators also posed an Environmental problem that had to be solved. B.D. Stone, a Project Engineer, with the Saskatchewan Wheat Pool, will review the technical negotiations that went into the solution between the Ministry of the Environment and his employers.

Because there was a lack of precise information in solving the problem available, trial and error experimentation transpired before a satisfactory solution was evolved. Mr. Stone will be telling you how the problem was licked and the corrective measures being implemented.

Other paper titles that interest me particularly during the conference include the discharge of heavy metals to municipal sewers; energy analysis of resource recovery options; the role of the Ministry in the disposal of liquid industrial waste in Ontario; and, controlling PCB discharges to the Environment. All of these subjects cover topics with which we are vitally concerned today.

In selecting these titles, or subjets, I am not ignoring any of the other 19 papers that are being presented. All the topics are important. What I am trying to emphasize is the variety that the Technical Committee has given to the program, attracting distinguished personages to present the

papers, selecting subjects that are challenging and current, and thereby continuing to develop a conference that attracts the high calibre of delegate that we have enjoyed in the past.

The PCB paper is of particular interest to me since I have been speaking out against these "Phantom Polluters" for the past six to eight months. I hope I can find the time to get back here to hear Nolan Curry, the Chief of the Chemical Systems Section of the New Yok State Department of Environmental Conservation, speak on this subject on Wednesday morning. It should be a good paper.

PCB's, asbestos, mercury and many types of plastics are all "Phantom Polluters" in my books. They are a nemesis because the scientific and corporate communities responsible for their development determined only their practical use and the contribution which these products would make to the "So-called Good Life." What they ignored were the long-term environmental effects.

Because of their shortsightedness, the natural environment has been damaged and in most cases we have been helpless to prevent it because we didn't know the consequences. We still don't know the sources of contamination with any certainty or the full extent of the distribution of these products through the environment.

Recently the Toronto Star ran a series of articles on pollution in the Great Lakes. The "Phantom Polluters" were the basis for these articles. Fortunately Environment Ontario has taken steps to control these polluters and eventually eliminate such hazardous contaminants as PCBs from industrial use. We welcome the new Federal Environmental Contaminants Act which is a major advance toward the elimination of the use of dangerous chemicals and substances. In the United States they have passed the Toxic Substances Control Act which has the same objective.

The day is coming when all products of a chemical nature imported into this country, or developed here, will be assessed as to their potential environmental danger before they are permitted to be used in industrial processes. This is a forward step in the right direction in making sure the quality of the environment, our environment, will be the best our collective efforts can attain.

I've been viewing the environment for a good number of years, and I must say that I am proud of our positive achievements and impressive record in Ontario. We are going to do more -- and if the past is any indication, our future efforts should be constructive ones.

Thanks again, Ken, for inviting me to address a few open -ing remarks to the 23rd Ontario Industrial Waste Conference. It's been my pleasure to be here -- I wish you well in your deliberations and sincerely hope that every delegate will profit from the presentation of these excellent papers. Thank you for your attendance and attention.

Tom Davey,
...tions and Science Editor,
... for Environmental Studies,
...ity of Toronto

Guest editorial

Ontario Industrial Waste Conference wins international reputation

The word *provincial* is commonly used in a disparaging sense to denote a lack of sophistication. But the 23rd Ontario Industrial Waste Conference, while undeniably a provincial effort, has developed an international reputation over the years. I have been attending the industrial waste conference for almost a decade now, attending my first as a session chairman when editor of *Water & Pollution Control.*

Unquestionably, over the years, it has developed into one of the great annual environmental conferences. The 23rd was no exception. Although the bulk of registrants came from Ontario, there was, as always, a healthy representation from across Canada and abroad.

The conference has retained its basic format presenting papers on "problem solving" and applied science, and these continue to be the bedrock of the annual event.

Over the years, however, and particularly at this conference, there has been a subtle but distinct shift in emphasis, reflecting a new sociological awareness.

Thus, the papers relating to the provincial and environmental assessment and review, plus the new awareness of the importance of the lawyer's contribution are welcome additions. The new awareness that energy analysis will play in solving of ecological problems is a good indication that the conference — in true evolutionary fashion — is adapting to contemporary problems.

For too long, the industry has ignored the political realities of environmental rehabilitation and the instruments of power went by default to other, more vocal bodies.

This willingness to shape the conference to the needs and imperatives of our time shows a healthy adaptability, and is probably why, in its 23rd year, the Ontario Industrial Waste Conference has become something of an environmental institution.

S E S S I O N   C H A I R M E N

ONTARIO INDUSTRIAL WASTE CONFERENCE 1976

SESSION I

J.A. Kennedy
Counsel, Thomson Rogers
Toronto, Ontario

(Papers 1, 2, 3)

SESSION II

C.J. Macfarlane
Regional Director
West Central Region
Ministry of the Environment
Stoney Creek, Ontario

(Papers 4, 5, 6, 7)

SESSION III

P.G. Cockburn
Regional Director
Central Region
Ministry of the Environment
Don Mills, Ontario

(Papers 8, 9, 10, 11)

SESSION IV

B.J. Wallace
Project Manager
Consumers' Gas Company
Toronto, Ontario

(Papers 12, 13, 14, 15)

SESSION V

R. Richardson
Commissioner of Works
Region of Durham
Whitby, Ontario

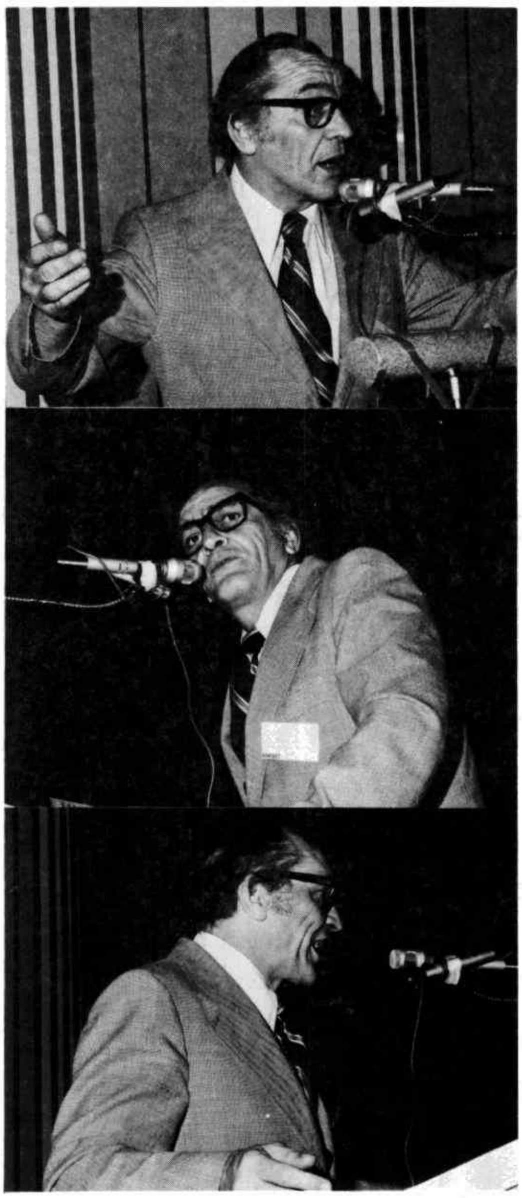
(Papers 16, 17, 18, 19)

B A N Q U E T   S P E A K E R

ONTARIO INDUSTRIAL WASTE CONFERENCE 1976

Joseph F. Forster
Manager, Public Relations and Promotion, and
Executive Assistant to J.B. Lombardi, President,
Radio Station CHIN AM-FM, Toronto

"The Humour and Heartaches of a Communicator"



Broadcaster, newspaperman, speech writer, humourist, promotional artist and public relations practitioner, Mr. Forster has spent all of his working life in the communications media, with a few years out for a stint in the Royal Canadian Navy and a mention in dispatches. He has worked on newspapers in Ontario and Quebec, been a radio news director and broadcaster, written for and acted on TV, and extended his creative and humouristic talents in the preparation of speeches and addresses for federal and provincial government ministers, municipal dignitaries, 'stand-up' comedians and others privileged to be exposed to the subtle Forster wit. In his address to the Conference delegates at the annual banquet, Mr. Forster reminisced about his many hilarious and serious experiences as a communicator, thereby providing his audience with a very definite contrast from the technical and scientific papers being presented during the Conference proper.

ONTARIO'S ENVIRONMENTAL ASSESSMENT ACT:

WHAT IT IS AND HOW IT'S GOING TO WORK

Ontario's Environmental Assessment Act is an important new planning tool designed to see that all relevant positive and negative effects of proposed undertakings are taken into account at a stage in the decision-making process when alternative solutions are possible. The Environmental Assessment Act emphasizes the environmental planning process. "Environment" is defined to include not just the natural environment, but also man, the man-made environment and social-economic factors. This recognizes that decisions on approval of an undertaking will involve trade-offs between different objectives.

Once it is part of the normal planning process, environmental and social costs and benefits of projects may be considered as routine as economic factors are at present.

Implementation of the Environmental Assessment Act will be phased, beginning with Ontario Government projects, extending next to municipalities, and commencing later for the private sector.

by

DENNIS P. CAPLICE

Director
Environmental Approvals Branch
Ontario Ministry of the Environment

Mr. Caplice, a native of Toronto, received his B.A.Sc. in Chemical Engineering (1959) and his M.A.Sc. in Sanitary Engineering (1961) from the University of Toronto. He joined the Ontario Government in 1959 and initially worked as a field engineer engaged in the investigation and control of industrial waste discharges. In 1963 he was appointed Assistant Supervisor in the Industrial Wastes Branch of the Ministry, in 1965 Assistant Director of the Branch, and in 1967 Director. In 1974 he assumed his present duties as Director of the Environmental Approvals Branch and heads a multi-disciplinary team involved in the review and approval of applications to the Ministry. He is a member of the International Joint Commission's Great Lakes Water Quality Board, and the Atomic Energy Control Board, Reactor Safety Advisory Committee.

ONTARIO'S ENVIRONMENTAL ASSESSMENT ACT:

WHAT IT IS AND HOW IT'S GOING TO WORK

BY:

D. P. CAPLICE

I have been asked to talk to you this morning about Ontario's new Environmental Assessment Act: What it is, the status of its implementation, and how it will affect industry.

Let me start by telling you what the Environmental Assessment Act is not. Put bluntly, it is not just another pollution control statute.

Rather, the Environmental Assessment Act is an important new decision-making tool designed to see that all potentially significant effects of proposed undertakings are identified and evaluated at a stage when alternative solutions, including remedial measures and the alternative of not proceeding, are still available.

I want to emphasize that the act is intended to bring about a consideration not just of the possible effects of a project on the natural environment - the air, land, water and plant and animal life - but to consider also the effects on man, the man-made environment, and on society, including economic factors. That is why the Environmental Assessment Act is more than a pollution control statute.

A second point I want to stress is that the Environmental Assessment Act is designed to operate very early in the planning and esign process. The reason for this is to ensure that Government and public review of potentially significant effects can take place at a time when options are still open. Too often in the past, there has either been no comprehensive evaluation of the implications of available options or this evaluation has only taken place after a proponent and the public have reached the point of confrontation.

This is what the act is trying to accomplish. Let me speak for a minute about how the legislation does this.

What the act says is that the proponent of an undertaking subject to the act cannot go ahead with the project until he has submitted an Environmental Assessment to the Minister of the Environment and the Minister has, first, accepted the Environmental Assessment and, second, given his approval for the project to proceed.

To ensure that this process takes place at the earliest possible stage, the act also stipulates that approvals under the Environmental Assessment Act must be obtained before any other provincial or municipal approvals can be granted and before the province can provide any loans or grants for the undertaking.

ONTARIO OF AN ENVIRONMENTAL ASSESSMENT

The content of an Environmental Assessment as set out in the Act have been very carefully constructed to ensure that all reasonable alternatives, along with their positive and negative consequences are evaluated by the proponent of a project subject to the Act. In essence, what an Environmental Assessment must do is document the process by which the proponent has proceeded from the concept stage, through consideration of alternatives, to the selection of a preferred undertaking for which approval is required. It is important to understand that this process is distinct from, and comes before, the preparation of the Environmental Assessment document.

While I am dealing with the contents of an Environmental Assessment document, let me point out that the act specifies that the alternatives being considered must be evaluated in terms of their advantages and disadvantages to the environment. But, to ensure that all potentially significant effects are identified and evaluated, the act defines "Environment" in a very comprehensive way. This definition includes:

1. The Air, land or water - what is defined as the "Natural Environment" in the Environmental Protection Act;

2. Plant and Animal life - and here it becomes interesting - <u>including man</u>;

3. The social, economic and cultural conditions that influence the life of man or a community;

4. The man-made environment, such as buildings or structures, or machines;

5. The effects of man's activities such as solids, liquids, gases, odours, heat, sounds, vibrations or radiation;
   AND

6. What may be called the ecological clause: parts, combinations or interrelationships between the previous components.

Given this broad definition of "Environment", I think you can see my earlier point that Ontario's Environmental Assessment process is directed at providing better information for decision-makers - not just in terms of effects on the natural environment, but, in terms of the entire range of effects that a project might generate.

Environmental Assessment is not intended to make natural environmental factors paramount. Rather it is intended to see that they are given fair weight and consideration in the decision-making process.

We recognize, and are willing to admit, that society, the Government, or the proponent have other objectives which may conflict with my Ministry's goal of protecting and maintaining the quality of the natural environment. The administrative process established by the Act is designed to see that all of these factors are carefully weighed, and perhaps traded-off, before a decision is made.

THE ADMINISTRATIVE PROCESS

Let me give you a quick overview of the administrative process established by the Act. It begins when the proponent prepares an Environmental Assessment Document and submits it to the Minister of the Environment for review. After consulting with other Ministries and agencies of the Government, in this review to see that their views are reflected, the Minister then makes public the Assessment and the review.

After a period during which the public may make submissions, including requests for a public hearing, decisions must be made. First, it must be decided whether to accept the Environmental Assessment, or amend it and accept it. Second, it must be decided whether the project should be approved, approved with conditions, or refused approval.

These decisions can be made in three ways:

1. Both decisions can be made by the Minister of the Environment, who can act by himself when deciding on acceptance of the Enviromental Assessment Document, but must act with cabinet concurrence when deciding the question of project approval.

2. If a hearing arises at an early stage in the process, the Environmental Assessment Board would make both decisions.

3. If a hearing arises at a later stage, the Minister of the Environment may decide on acceptance of the Environmental Assessment and the Environmental Assessment Board decide on the project approval.

Where the Environmental Assessment Board makes decisions, the act provides that within a set period these decisions may be changed by the cabinet. That, very briefly, is the administrative process established by the Environmental Assessment Act.

I would like you to note that whether the Minister or the Board is deciding on project approval, the cabinet always has an opportunity to become involved in this decision. This recognizes that the decision on project approval will often involve trade-offs between legitimate but competing or conflicting objectives of Government.

Under our Parliamentary System of Government, it is appropriate that the cabinet and not a single Minister or an appointed board, is ultimately responsible to the legislature and to the people for determining which values or objectives are to be given the most weight.

IMPLEMENTATION

Turning to implementation of the Act, we fully expect that it may be necessary to refine and streamline administrative procedures as we gain experience. Therefore, the legislation will be implemented on a phased basis.

In the first phase, expected to begin shortly, the Act will apply to projects and programs initiated by Ontario Government Ministries and Agencies such as Ontario Hydro.

Municipalities will be exempted from this initial phase in order to allow time for discussions with municipal representatives about the types of municipal undertakings which should be subject to the Act or exempted. A joint committee has been established with representatives from my Ministry, the Municipal Engineers Association and the Municipal Liaison Committe

The Act requires that a separate proclamation be made to bring it into force for the private sector. I expect that the general application of the Act to private industry will begin only after we have gained some experience with the Assessment and review of Government projects. In the interim period, however, the Premier has stated that it may be necessary to individually designate certain major projects if it is in the public interest to do so.

I should also mention that when the Environmental Assessment bill was before the legislature, the Minister of the Environment gave the assurance that the Act would not have general application to the construction of housing in Ontario. However, the Minister also reserved the prerogative to designate housing projects which appear to present a particularly significant threat to Environmental quality. My own interpretation of this is that normal residential development will not be affected if Environmental concerns can be adequately handled under existing approvals processess. We have no desire to add an additional layer of approvals to housing construction if existing processes are doing the job.

EFFECTS ON INDUSTRY

I know that this group is particularly interested in how the Act will affect industry. For the private sector, the legislation states clearly that environmental assessment will be required only of those kinds of undertakings which are designated by regulation. This provision reflects the legislature's intent that the act be applied not to all projects, but rather only to major projects with the potential to generate significant and complex social, economic and environmental effects.

A screening process, involving consultation with affected industry groups will determine the type of private sector undertaking to be designated. In making the determination, the major criterion is the significance of the potential effects of a given type of undertaking.

However, other factors enter into this decision. One is the need to keep the number of projects designated within the limits imposed by the resources available for the enviromental assessment review process. A second is the degree to which it seems likely that an adequate review can be achieved by existing approvals processes.

VOLUNTARY ENVIRONMENTAL ASSESSMENT BY INDUSTRY

While the Act will not generally apply to industry until the third phase of implementation, you should be aware that a number of industries have already prepared and submitted Environmental Assessments on a voluntary basis. Other such assessments are currently being prepared.

I would speculate that the companies which have chosen to prepare Environmental Assessments thus far have chosen this route for one or more of the following reasons:

1. There is no better way to get experience in what an Environmental Assessment involves - experience that will prove valuable once the Act becomes formally applicable.

2. Many of these companies have recognized that there is a considerable advantage to getting input from Government agencies and from the public early in the project planning process. The Environmental Assessment provides an ideal format for doing this. Problems can be identified and resolved more economically at this stage than further along in the design process. These Companies have also probably recognized that early consultation means that subsequent approvals come easier and faster.

3. There is a very real advantage in public relations to be gained by voluntarily complying with the intent of the Environmental Assessment Act. Actions speak louder than words, and such voluntary compliance means more to the public than pages of corporate advertising.

Whatever their reasons for choosing to submit Environmental Assessments, and I am sure there are more than I have mentioned, these voluntary Environmental Assessments have been very useful to us in Government and I think that they have also benefitted the companies involved.

Let me give you some examples of what I mean:

In one case, a voluntary Environmental Assessment was prepared for a proposed paper mill expansion in Northern Ontario. From the Company's viewpoint we have learned that the more rigorous and systematic analysis required to prepare the Assessment produced a number of internal benefits such as improvement in problem identification, design, work scheduling, and community relations.

From the viewpoint of the Government, the Environmental Assessment document provided a better basis for an overall Government response to the proposed project and proved most useful in determining the appropriate conditions of approval under the Ontario Water Resources and Environmental Protection Acts. Other Ministries have also found the Environmental Assessment a useful document in arriving at their own decisions about the project as all of the relevant information is collected in one place.

Municipalities to be affected by the increased work force required for the project made extensive use of the Environmental Assessment Document in preparing their own submissions to the Government outlining their requirements for provision of water and sewer servicing, education, health care, and other community services.

The project is now being implemented and as it unfolds it is interesting to watch the effects occurring as predicted. Perhaps one of the major benefits of this process has been the removal of much of the uncertainty about what is going to happen, and how problems are to be resolved.

Another example I would like to cite involves a small steel foundry seeking to expand in Central Ontario. Again in this case, the Company's own design process benefitted from carrying out the Environmetnal Assessment, but the most remarkable benefit was in community relations. The small centre where the company ultimately proposed to locate its foundry operation had recently been the location of considerable environmental controversy surrounding another Company. By conscientiously studying the effects that the foundry might have on the community and the natural environment, and by providing an opportunity for the public to contribute to this process, the steel company has received very favourable community reaction.

Indeed, a lead editorial in the local newspaper praised the Company for its voluntary compliance with the principles of the Environmental Assessment Act. Without mentioning the name of the Company, let me quote you the editorial:

(This Corporation) Has A Better Idea

If the current procedure being carried out by (this) corporation is a sign of things to come, Environmentalists may have reason to be hopeful. (The Corporation) is planning to expand its current operation in (Our Town) with a $3.5 million foundry, located on its present property......

Though not yet compelled by law, the Corporation..... had decided to follow the guidelines for industrial expansion as laid down by the Provincial Environmental Assessment Act of 1975.

(The company) had hired a private Environmental Consulting group ... to research the possible effects of the new foundry. The group has begun investigations into all areas of ecology from noise level to possible effects on the erosion of the nearby Lakeshore. To date the environmental group has found nothing which would give reason for concern about the proposed expansion.

Along with the ecological studies, (The Company) want to involve the residents of (Our Community). The Corporation wants to find out how people feel about a foundry in their Town. They are interested hearing the good and the bad.

(The Company) has already planned to hold a public meeting in order to receive input from the town citizenry. If problems are raised as a result of that meeting, the Corporation proposed to hold another public meeting in order to report back to the community.

This style of environmental preventive medicine is an encouraging development in the industrial field. (The Company) is to be commended for initiating the action.

What I am trying to suggest to you through these examples, is that the environmental assessment process, while it is primarily designed to improve Government decision-making, has many advantages to offer to proponents. In the period before the Environmental Assessment Act generally applies to industry, those of you whose companies may be involved in major expansions or development of new plants or locations might be wise to consider voluntarily complying with the spirit of the Environmental Assessment Act.

From the experiences I have mentioned, and others, I think that your Company might derive some real advantages from the process. At the very least, you can gain some experience in the process while mistakes are stil relatively cheap - before the law comes into force.

HOW NOT TO DO AN ENVIRONMENTAL ASSESSMENT

Speaking of mistakes, our experience to date with both the public and the private sector has also provided us with some useful lessons in how not to do an Environmental Assessment:

- Don't, and this is most important, assume that an environmental assessment is an after-the-fact justification of a project proposal you have already decided upon through standard technical and economic procedures. Rather, the essence of Environmental Assessment is that you consider all relevant factors as you are proceeding from identification of a problem or opportunity through evaluation of structural and non-structural alternatives, to the selection of the preferred project.

- Don't wait until you are ready to start construction before submitting an Environmental Assessment for review by the Government. Environmental Assessment fits in at the planning and preliminary engineering stages, not at detailed design.

- Don't leave out the public until the last possible moment. If there is one major cause of expensive and time-consuming confrontations between the public and project proponents, it is that the public has not been consulted until the proponent has become firmly - often inflexibly - committed to a specific course of action.

- Don't spend your time developing more detail than you need. The rule of thumb we intend to use is that the level of detail need only be sufficient to support the kind of decision for which approval is requested. For example, when you are considering conceptual alternatives or merely seeking to identify siting possibilities, the kind of data you need can probably be found in your library. But when you get down to making the final choice of site, or considering how the site is to be utilized, it is more likely that your data must be obtained by field investigation.

Early Consultation Important

Turning from what you should not do, I want to suggest strongly that once you decide that an Environmental Assessment is required or desirable, your first move should be to contact the Environmental Approvals Branch of the Ministry.

Staff of the Environmental Assessment Section of this Branch have prepared guidelines which outline, in a general way, what should be contained in an Environmental Assessment Document. These content guidelines will be available once the Act comes into force.

But more important, by getting in touch with the Ministry before you start work on an Environmental Assessment, our staff will be able to sit down with you and translate these general guidelines into a more specific outline of what should be done in your particular case.

For example, we can point out any "red flags" in your proposed study area. We can also suggest the level of detail that is likely to be appropriate at each stage of the study.

In these preliminary consultations, the question of what methodology to use in your study can also be discussed. While a number of different methodologies have been developed, the Ministry has steered away from advocating that a specific methodology, and only that methodology, is appropriate for a given type of project. Rather than taking a "cookbook" approach, we consider that each project is unique and occurs in a unique spatial setting and that the methodology should be selected accordingly.

CONCLUSION

I have had a lot to say this morning about what might be expected of you as environmental assessment begins to play a role in Government decision-making on major projects. I would like to close by giving you an idea of what you can expect from us.

We are committed to making the environmental assessment process a useful and workable planning tool. I would be foolhardy to suggest and naive to believe that it will be possible to implement such significant legislation as the Environmental Assessment Act without any snags or hitches. But we plan to sort out these problems and make adjustments and changes - even legislative amendments - as they become necessary.

So what you can expect from the Ministry of the Environment is a reasonable, practical, and pragmatic approach to implementing environmental assessment in this province. If you encounter a problem, come and talk to us. We are willing to listen and we will try to resolve it.

A CRITICAL REVIEW OF THE FEDERAL ENVIRONMENTAL ASSESSMENT AND REVIEW PROCESS

The Federal Environmental and Review Process (EARP) envisions a review of environmental concerns early in the planning process, applicable to Federal programs, projects and activities. In practice it has tended to be project-specific and, with exceptions, to come late in the decision-making process. It is part of the maturing process of a new, young procedure. The project-specificity is good in itself, but lamentable overall. It means giving attention to the trees, but not to the forest. This must be changed.

Part of the difficulty arises from the fact that Governments are more concerned with short-term (5 - 10 years) planning than with long-term planning. The overall environmental effects of all projects are more important in the long-term than in the short-term.

This process also needs to improve its public credibility by more open, early dialogue with the public.

by

DR. R. REED LOGIE

Chairman
Environmental Assessment Panel
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Dr. Logie, a native of Chatham, N.B., received his B.A., majoring in biology, from the University of New Brunswick and his M.A. from the University of Western Ontario. He completed his Ph.D. at Rutgers University in New Jersey. Following five and a half years with the Canadian Army he joined the staff of the Fisheries Research Board of Canada and in 1946 was appointed Associate Scientist in P.E.I. In 1959 he became Regional Supervisor of Fish Culture Development in Halifax. Then in 1965 he was appointed to the position of Assistant Deputy Minister of Fisheries, and in June of 1971 he assumed the position of Secretary to the Canadian Environmental Advisory Council when the new Department of the Environment was formed.

A CRITICAL REVIEW OF THE FEDERAL ENVIRONMENTAL ASSESSMENT AND REVIEW PROCESS

by

DR. R. R. LOGIE

Public environmental concern in this country is a little less than ten years old. The federal Department of the Environment, which focussed most of the Environmental concerns of the federal government in one department is about six years old. The federal EARP is two and one-half years old. It is perhaps proper to pause now and take a critical look at what has been the track record of the institutions in responding to the environmental concerns of the public. First, we should thoroughly understand the nature of the three integers in our equation: the federal Department of the Environment, the federal EARP and the public concerns.

Let us commence with the Department of the Environment or, even further back, with the meaning of the word "environment". There are certain words in English -- and in other languages -- that everybody professes to clearly understand, but nobody is really willing to define. "Love" is one of these in English and "aimer" is even more so in French. "Environment" is another in both English and French. Consider the differing ways in which we use the word in English: the physical environment, the natural environment, the cultural environment, the family, home, religious, educational or political environments -- and many more. Is the word "Environment" as used in "public environmental concerns" or in "Department of the Environment" expected to catch up all these diverse meanings? Certainly not! Where then may we turn for enlightment? We might ask the scientists who take pride in being precise about such things. The most common answer would be "the biosphere", that is to say, those portions of the land, air and water of this planet in which life is possible. But a large and growing body of scientists would want to include the life itself. The definition is then altered to "the biosphere and the biota" or in common terms, the physical environment plus the living resources in it. Immediately another argument develops: "is man to be considered as just another member of the biota, just another living resource"? Or,in other words "are social effects simply the environmental effects on humans"? There are no universally accepted answers to these questions, but let us leave them for a moment and examine how they have been addressed.

In the Ontario Environmental Act, 1975 the following appears:

1\. (c) "Environment" means,

(i) air, land or water,

(ii) plant and animal life, including man,

(iii) the social, economic and cultural conditions that influence the life of man or a community,

(iv) any building, structure, machine or other device or thing made by man,

(v) any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from the activities of man, or

(vi) any part or combination of the foregoing and the interrelationships between any two or more of them,

in or of Ontario.

This clearly suggests that "the environment" comprehends the biosphere and the biota but focusses on the interrelationship of man with his physical environment and other living things. In Ontario, this is the law. By contrast, British Columbia appears to be setting up a Department of the Physical Environment, with the living resources in other departments and with the social concerns a matter for the whole government. Elsewhere in Canada, we find provincial departments of Municipal Affairs and Environment, Tourism and Environment, Resources and Environment and even, at one stage, Fisheries and Environment. Obviously, there isn't a provincial consensus. Let us look for illumination to the pellucid logic of the federal government.

The creation of a federal Department of the Environment was first mooted in the Speech from the Throne in October, 1969. In this speech and in the debates in the House that ensued, there were airy references to "maintaining the health of the biosphere" and to "man's stewardship responsibilities for the biosphere" -- and for the other living creatures unfortunate enough to co-inhabit this planet with him. When Parliament got down to the brass tacks of debating the Government Organization Act, 1970, which among other things set up the Department of the Environment, certain pragmatic considerations intruded rapidly on this philosophical orgy.

(1) the government did not intend to create a single department in which all of its environmental concerns would be centered;

(2) neither did it intend to create a department in which all of its concerns for living resources would reside;

(3) it recognized that most of the legislative clout in matters of environment and resources rested with the provinces.

(4) it did not define the word "environment".

What came to pass therefore was not a Department of the Environment, but a "Department of Those Portions of the Federal Environmental Concern and Those Portions of Federal Living Resources Concern Delegated to a Department to be Known as the Department Of the Environment Without Prejudice to Provincial Concerns". The advantage of calling this strange assemblage a Department of the Environment is that one can use the cute abbreviation DOE instead of the abbreviation for the longer title I have just quoted, which comes out as DTPFECTPFLRCDDKDOEWPPC. Even in these days of bureaucratic alphabet soup, this is a bit too much. The government's fear of a larger, broader Department of the Environment was of course based on two considerations:

(1) it would be a colossus;

(2) it would intrude on the decision-making authority already vested in other ministers.

What Parliament actually did was to include in DOE only those living resources over which there was a federal mandate, and not all of them, and those environmental concerns on which DOE could "coordinate" the efforts of OGDs or talk to the provinces. This is then a department with line, administrative authority over certain resources and an advisory capacity with respect to bits of the biosphere and the biota.

The next federal step came in June, 1972 when the Cabinet authorized DOE to control -- and indeed rollback pollution from federal activities. This was followed in December, 1973 by another Cabinet Decision setting up the federal Environmental Assessment and Review Process. This is the process under discussion here today.

It is important to understand what EARP is intended to do, before one can assess how well it has done it. The process is limited to federal projects because this is the limit of the federal jurisdiction. Federal projects are defined as those involving federal initiative or funding or federal property or lands. The process really splits into two parts. In the first part, federal departments and

agencies are directed to consider the environmental effects of their programs, projects and activities, before coming to "GO" decisions. Emphasis is laid on doing this early in the planning process. Their appreciation of the environmental impacts of what they plan to do has come to be known as the Initial Environmental Evaluation and is a factor in their own decision making. There is no compulsory reference to the Department of the Environment. In the second part of the process they refer their plans to DOE for review if they consider the environmental impacts to be significant, or, in fact, if they are not sure. Once this reference has been made, the project may not proceed until the review is complete. The Cabinet has instructed DOE to administer this review and has laid down the procedure to be used. Briefly it directs the establishment of an Environmental Assessment Panel, chaired and largely staffed by DOE but including one member from the other government department concerned (the Initiator) to:

(1) provide guidelines for an Environmental Impact Statement to the Initiator;

(2) review the Impact Statement for credibility and completeness, calling on any advice from any source that it may need;

(3) make the Impact Statement available to the public and obtain the public response;

(4) report to the Minister of the Environment advising him of the significance of the environmental impacts.

It is necessary at this time to say something about the nature of public concern. Perhaps the wisest thing to say and to do would be to say that there are many differing public concerns and that it is therefore quite impossible to say anything very wise and to leave it at that. But at a time like this, one is obliged to go on, so let's press ahead in what is a very tricky area. There can be no doubt that the history of industrial expansion in this and in other developed countries has also been the history of gross, unnecessary environmental degradation. The land, the air and the water were used by industry as a pollution sink. Natural resources were over-exploited; landscapes permanently defaced; species extinguished. Public reaction against these tactics became translated into political concern and into departments of the environment in political jurisdictions around the developed world. I do not believe that "the waste, destroy and pollute" philosophy permeates many, if any, corporate board rooms in Canada today. But a segment of the public is still deeply suspicious and

this will not soon be overcome. Many people believe that the bureaucrats will not enforce the rules, that industry will not obey them and some believe that the bureaucrats, or indeed the politicians, and the tycoons are jointly conspiring to delude the public. The first public concern is therefore SUSPICION.

The second is a failure to understand the nature of our economic system and our life-style. In this the public is in eminent company: The senior politicians and the senior economists in the land. I do not profess to be superior to this lot, but I want to make some basic points that are often missed. It is human beings and human beings only that cause environmental damage on any significant scale. It is not the birds and the bees and the flowers, nor the panthers, the parrots or the petunias; it is ungrammatically, but undeniably, us. We cause damage by a combination of our sheer numbers and of our industrial economic and social styles. These styles dictate that our economy must expand. Expanding economies consume non-renewable and renewable resources and physically degrade the biosphere. One thus arrives at a classical dilemma: the process you must have creates the effects you don't want. This inevitably means trade-offs: the tolerance of some environmental damage for some economic gain, except in the grossest cases of environmental damage. The trade-off decision is and should be, a political decision. It is inherent in the dilemma that the political decision offends some segment of society. The public, by and large, does not understand this dilemma. A considerable number want, explicitly or implicitly, both economic growth and cessation of environmental damage. So do I, but I realize that the horns of a dilemma never meet. The second public concern is therefore founded on MISUNDERSTANDING.

The third concern is based on IGNORANCE and I do not say this in any pejorative way. We live in a highly complex technological world and environmental impacts of highly complex technological undertakings are apt to be expressed in professional or technological jargon which is in itself a form of shorthand for communication among professionals but which is outwardly completely unintelligible gobbledegook to the general public. I suggest to you for example, that, with the best will in the world, it would be difficult to explain in one session or one brochure to the person in the street all the complexities of a nuclear reactor in electric power generation. It is considered less than helpful for this person to read in the Impact Statement that there is environmental concern about seismic stability, impingement and entrainment, Derived Release Limits (in Micro-Curies) and reduction in harpactecoid copepods. Really!

I would like to re-phrase IGNORANCE to LACK OF INTELLIGIBLE INFORMATION. And I don't mean information which is intelligible to the giver; I do mean information which is intelligible to the receiver.

I am going to mention one final concern, because it is real, not because I have much sympathy with it. I shall call it FANATICISM. I am sure you have all encountered it. This is put forward by the single, simplistic solution boys and girls, who, of course, frequently argue among themselves. As examples: all our troubles would cease if we could achieve, tomorrow or at least next week, any one of the following:

(1) Zero population growth

(2) Zero economic growth

(3) Zero energy growth

(4) Zero nuclear growth

(5) A vegetarian society

(6) A matriarchal society

(7) A truly Christian society

Such of these as you may like are surely planks in a platform, but none of them will be implemented tomorrow nor even next week. Nevertheless, since trade-off decisions are political and since persons who hold any one of these views have the vote, they are political integers. No doubt a supply of intelligible information would convert some to a more comprehensive view.

After this long introduction, I arrive at the meat of the matter: How have we done in our own estimation and in the public view? In brief, the process lacks public credibility for a number of reasons. Let us examine them briefly with an eye open to solutions.

First, the participation of federal departments and agencies in the self-assessment of their programs, projects and activities EARLY in their planning. Some are preparing Initial Environmental Evaluations, and the number is growing, but few are early enough in the process and all are project-specific. None concern broad programmes in the feasibility stage of planning and none concern groups of projects. For example the Mackenzie Valley Corridor: Each of these pieces is environmentally considered separately; gas extraction, gas purification; chilled gas pipelines in the territories; connecting chilled gas pipelines in the provinces; hot oil extraction and pipelines in the Beaufort Sea and in the territories; connecting hot oil pipelines in the provinces; infra-structures in the territories, such as roads, maybe railways.

Nowhere is the whole development considered environmentally as a whole. Nor are the aggregate environmental and social effects of "industrializing" the North considered as a package, except perhaps by the Berger Commission. And that is perhaps more attributable to Justice Berger's interpretation of his terms of reference than to their intent. There is no doubt that the federal process of environmental assessment must become involved in the earliest stages of planning of federal projects and programmes and must be free to consider the incremental effects of a series of projects in a programme while not relinquishing its vigilance over individual projects. How is this to be accomplished? At the moment it must be accomplished mainly by persuasion, leading to a conviction in government departments that this course is both necessary and beneficial. What we really need but do not want is a magnificent blunder in which some minister gets environmental egg all over his face. Or it can be accomplished by force; by the force of strong public stands by Ministers of the Environment, which are, in fact, emerging; or by the force of environmental assessment law. Environmental assessment law is, in my personal opinion, a mixed blessing, but on the federal scene it will, again in my personal opinion, emerge only when the existing process is seen to have failed which is not yet.

The second criticism is the failure of environmental assessment to enter into long-term planning say more than ten years into the future. The first observation about this criticism is that EARP has not entered into long-term planning because there is no long-term planning on any comprehensive basis, to which EARP could contribute or to which it could respond. This is an absurdly simple excuse. Why are you not playing the ball game, my son? Because there is no ballgame, Daddy? It also begs the question: "If so many people want to play, why is there no ball game, my son"? The answer is complex and really involves the great dilemma of government today. Let us recall that only masses of humans cause environmental damage and that they do so because of the life style they demand, which in turn requires an economic system based on perpetual growth. It is this economic system which sustains the life style we demand and which causes the environmental damage we deplore. If one slows down the growth in the economic system, there is great benefit to the environment, but all sorts of undesirable side-effects appear. At the same time it is apparent that the increasing utilization of non-renewable resources by "a healthy and growing economy" cannot go on forever. How then do you tinker with this machine without causing instant armageddon, particularly when it is now abundantly obvious that not even the economists know how the economic machine works?

It appears that governments are baffled by this dilemma and are keeping the old machine creaking on by emergency repairs, until somebody figures out some answers. My essential point, however, is not to embark on a sea of economic speculation, but to make and to reinforce a point (call it Logie's law if you like; Murphy has a law, why should not I have one.):

> Unless one first envisions the economic future, one cannot see the environmental future, because the two are related as cause and effect.

As resources grow scarce and demands increase, governments will have to produce solutions, but they do not appear to be doing so now, even though it is clear that the long-term effects of resource exhaustion and environmental damage could be cataclysmic.

Finally, there is the matter of effective public participation in environmental decision making, which it is a function of the EARP Panels to obtain and to convey to our Minister. We are not good at it. In fact we are poor at it. But hopefully we are learning. When I am asked to speak on this subject, I invariably call to mind a character in the Lil Abner comic strip known as Silent Yokum. "He never said nawthin' about nawthin', mainly on account of he knew nawthin' about nawthin'. I should invite you to meet Silent Logie, but of course I can't. Since I haven't much to say, I'll be mercifully brief. Massive public information programmes would help, but would also have a tendency to overwhelm and confuse, because of their mass. I might propose all sorts of solutions, but I, in the manner of the fanatics, will go directly to a single, simplistic solution, at least as the most important thing to do. I refer to "open planning". By this I mean the planning of programmes or projects by their initiator at open meetings with the public or representatives thereof. I see no reason why government-sponsored projects cannot be treated in this way from the earliest stages of feasibility planning. I can see some reasons why industrially sponsored projects frequently cannot reach quite this far back, but neither do I see any reason for delay until the last moment. One of the most important features of such open planning sessions would be the transmittal of professional and technological information in plain language, the patient explanation of jargon. In my opinion this is the most effective way of transmitting information about the project and its effects to the people who are concerned with receiving it. Whatever else might be done by way of public information, I am convinced that this must be done.

In final summation, Mr. Chairman, I believe that EARP is intrinsically a good process, but that it must be improved in the ways I have suggested. It lacks credibility, without which it cannot survive. I have no idea how destructive this sentiment might be if applied to all government procedures, but it makes for interesting speculation, doesn't it.

ENVIRONMENTAL IMPACT ASSESSMENT:

INDUSTRY'S NIGHTMARE OR LAWYER'S DREAM?

This paper provides a critique of Ontario's proposed environmental assessment procedure.

It also deals with the expected requirements in terms of proposed research and testimony of an environmental assessment. The scope and complexity of environmental assessment is considered in terms of the role of the Ministry of the Environment, the Environmental Assessment Board and the parties to an assessment hearing including the public.

by

C. CLIFFORD LAX

Council to:
Morris, Bright, Rose
Toronto, Ontario

A native of Quebec City, Province of Quebec, Mr. Lax received his B.A. from McGill University in 1965, a Bachelor of Law from the University of Toronto in 1968 and was called to the Bar of the Province of Ontario in 1970. He is a Past President of The Canadian Environmental Law Research Foundation and a Director of The Canadian Environmental Law Association.

ENVIRONMENTAL IMPACT ASSESSMENT:
INDUSTRY'S NIGHTMARE OR A LAWYER'S DREAM?

by

C. CLIFFORD LAX

It is a rare opportunity which has been granted to me today, to appear before you in my role as a lawyer whose practice involves a considerable amount of environmental litigation and to discuss with you my hopes and fears about the process of environmental assessment; for while I have no doubt that directing our minds to an assessment of the potential harm of a proposal or undertaking prior to construction is an eminently reasonable suggestion, nonetheless, I am concerned that the legislation, the civil servants, the technical experts and the lawyers could, if permitted, effectively smother this thought-provoking process while still in its infancy. There can be no doubt, that the process of environmental assessment like any other new idea, will require time to nurture itself and to develop into a process which will be regarded as a normal and expected step in the governing of our society.

Unfortunately, the concepts of preventive care and long term planning have never been strongly held in our society. For example, if one would look through the law cases going back for well over a century, the observer would note that in those situations involving environmental contamination, the victim or the state were awarded a monetary sum, which, supposedly was intended to represent the cost of the harm. Pollution was treated in much the same way as a motor vehicle accident. If you are struck and as a result your arm is fractured, you are awarded a certain sum of money as compensation.

When environmental degradation became more than a simple matter of local contamination, and when the costs of the damage

caused by this contamination far exceeded the ability of any expert to effectively arrive at a calculation, and in fact, when clean-up proved to be impossible, we were forced to rethink our "carrot and stick" approach to environmental regulation. As you know, in the past, we have dangled certain rewards in front of polluters in the hopes of getting them to voluntarily abate their emissions. Upon their failure to abate their emissions, we have attempted with minimal success to invoke the penal sanctions of the law to punish the offender. In almost all instances, the cost to society caused by the damage of the pollution far outweighed the amounts recovered by way of fines and court costs.

I do not know any commentator, even those locked in the bowels of industry, who have attacked the conceptual premise of The Environmental Assessment Act. What thoughtful person would attack the stated purpose of the Act as contained in Section 2, in which the Act is intended "for the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise manangement in Ontario of the environment"? One observer has suggested that since the words "betterment of the people" are of prime importance in the wording of the statement, that the well-being of flora and fauna are not relevant to the purposes of the Act except as they may relate to a change in the well being of the people.[1]

[1]The Environmental Assessment Act - Workable or Unworkable? Address by David E. Toye, Gulf Oil Canada Limited to the Association of Professional Engineers of Ontario, April 22, 1976.

Such a suggestion is to unduly narrow the scope of Section 2 and to forget the lessons of the excesses of the past two decades. Whenever man has interfered with nature's processes, whether unwittingly or by design, that interference to the apparently most insignificant aspect of nature has had a repercussion on the quality of human life. Every activity that man engages in has a direct effect upon the environment and upon not only the well being of this generation, but the potential well being of future generations.

That this Act is being introduced now may surprise some. Many people think that the environmental movement, so called, is now a dead issue. This viewpoint is reflected by the apparent loss of power and prestige of the Federal Department of the Environment. I think it is true that environmental concerns are to some extent being down played and certainly do not have the prominence in newspapers that they were accorded a decade ago. However, I invite you to think about the revolutionary changes that have occurred with respect to our perception of the environment in the last decade. Let me give you an example. I am sure you all recall the Buick automobile of the early and mid-1960's. By comparison to today's car, it was a monster. You remember the large sculptured fins and the huge roomy interior. The designer's chief concern was opulence and style. Form and function were down played. That car is as dead as a dodo bird and within one decade, those kinds of automobiles including the Cadillac El Dorado, have become extinct. In a sense, the automobile may have reached its apex in terms of

luxuriousness in the mid-1960's. We are now being exhorted to buy the new trim sized model of motor vehicle including the personal sized Seville. How did our perceptions and tastes change so radically?

Let me give you another example of how our perceptions have changed. How many in this room were concerned about the increasing amounts of garbage being produced by the Province of Ontario in the mid-1960's. I would be surprised if there was more than a handful of you. The concept of recycling was foreign to us because the concept of the finiteness of our resources was also foreign to us. We were blithely assured by the petroleum companies, the primary resource extractors, and our government, that the combination of exploration and technology would ensure limitless supply of natural resources. How quickly things have changed. Within a decade we have become concerned about long term planning and about long term assurances of the supply of natural resources required to sustain not only life, but a reasonable standard of living for Canadians.

Long term planning has never been a forte of western democratic societies. Indeed, communistic and socialistic countries purport to set their priorities in terms of long term objectives. The reason for this failure on the part of western governments is obvious. A government is elected for four years and priorities are usually set within that time frame. There are very few votes to be earned as a result of intelligent long term planning. In any event, there is no guarantee that the policies adopted today will be implemented

by another government ten or fifteen years from now. As a result, long term planning, has, for the most part been relegated to the civil servant, or to special consultants retained for that job. The quality of our environment today reflects the shortsighted views of the past. The Environmental Assessment Act is, I believe, a hopeful sign that our planning priorities are being reversed. For the revolution of the past decade, the death of the large finned Buick and the burial of our naive belief that technology would always provide for future generations,has resulted in the concept of this Act.

Perhaps, most importantly, the Act passionately accepts the notion that decisions about the environment are the domain of the public at large and not the subject of discussion only between the government and the regulatee. Section 6(2) of the Act provides that any person may inspect an environmental assessment and may make written submissions to the Minister with respect to the environmental assessment, or by written notice to the Minister, require a hearing by the Environmental Assessment Board with respect to the undertaking. This recognition of the fact that the environment is within the public realm of discussion and is not to be considered in light of private rights, is most important. In fact, I believe it is the most revolutionary aspect of the legislation. For while I may not live, for example, in the area of Port Hope, I nonetheless, have a very serious and substantial concern of the effects of radiation contamination. My concern as a

citizen in this Province, is the only concern required to give me status to speak about it. The fact that I do not live in Port Hope nor do I own property in Port Hope is of no significance. The hazards of radiation contamination will long outlive any of the current residents of Port Hope. The contamination will continue to affect the natural environment of the Province of Ontario for something over five hundred years.

Let me give you another example. I do not live in the vicinity of any of the lead smelters in Metropolitan Toronto. No member of my family has, to the best of my knowledge, been adversely affected by their activities to date. However, as a citizen and tax payer of this Province, I currently bear and shall continue to bear a portion of the expense involved in the medical treatment or cost of environmental clean-up resulting from the lead contamination in the vicinity of those plants. Again, the toxic effects of the lead will be felt by not only this generation, but by future generations to come. Those considerations are sufficient to give me a right of standing and a right to be heard.

My right of standing derives from the fact that I am a citizen. The air that I breathe, the water that I drink, and the noise that I am subjected to, are facts that I share in common with all other citizens. It is trite but necessary to state that we have the right to expect clean air, clean water and an environment generally unfouled by contamination of any kind. That statement, mustof course, be tempered by recognition

of actual fact, and it for that reason that The Environmental Assessment Act will provide a formal mechanism through which the decision can be made as to those levels of environmental purity which we choose to maintain while maintaining a life style and standard of living within the expectations of the citizenry.

While I have talked in rather philosophical and vague terms about the right of standing, I should also talk about the potentiality for abuse. Much has been said both by industry and by legal spokesmen of the Ministry of the Environment as to the potential frivolous use of the provisions of this Act by certain members of society. In my view, that concern is not unfactual but it is unrealistic. The courts of this land have always held themselves open to any suit. There is no predetermination of the validity of the suit. Yet, in my experience, abuse of the process by virtue of the bringing of a frivolous action is a rare occurrence indeed. On those rare occasions when it does happen, I have found the courts ready and willing to chastise and punish the person who seeks to waste their time and the public purse. I have no doubt that the Environmental Assessment Board will be able to control its own process. I have no doubt that after they have gained some experience, they will be able to quickly ascertain which applications are frivolous and which objections are founded upon a reasonable basis. While much has been said about the American experience, the most recent evidence suggests that very few of the objections taken are frivolous. It seems strange to me that with respect to most other matters, our government starts with the supposition that the citizenry is

relatively well-educated, well-informed and well-motivated. Yet the stated concerns of some of the officials of this Ministry have precisely reversed that underlying belief. Citizens and citizens' groups are depicted as being devious, mischievous and troublesome. In fact, in a recent speech to a meeting of a section of the Canadian Bar, one of the officials of the Ministry is reported to have described the Canadian Environmental Law Association as a "Stalinist" organization.

My concern is simple. This Act cannot work unless the Board proceeds on an assumption of good faith with respect to all of the parties before it. It has been said that Mr. Justice Routledge of the American Supreme Court believed all men honourable unless proven otherwise. The same articulation of faith must be apparent in the statements and activities of the Environmental Assessment Board, if their process is to work.

Let me talk to you for a moment about my concern with the possibility that the entire process we are talking about today, will become the private domain of technological experts, bureaucrats and lawyers.

Let me start with my concern about the lawyers since they are the profession with which I am most familiar. Lawyers are probably the most maligned profession amongst the general public. They are also, I think it is fair to say, the most feared profession. That fear and resentment is based partly in fact and partly in misconception. The fact is that lawyers are trained to fight. That is why the very people who malign lawyers are also the first to consult a lawyer when they are faced with a dispute or problem which they cannot handle

themselves. Lawyers are trained in the art of advocacy or the skill to present the position of his client.

Now, why would I be worried about the involvement of the lawyer? Clearly, I have no concern about the fact that lawyers will inevitably take part in the process. Every person has the right to counsel and very often, a trained advocate can shorten matters by getting to the very heart or nub of the issue. Similarly, the advocate trained in advocacy can at times put forward a point of view more effectively than his client could have. Finally, the lawyer can very often marshall the evidence and present it with an objectivity and direction which his client cannot bring to the issue.

My concern is rather with the inevitable tendency for a lawyer to "legalize" the process. By "legalizing" the process, I do not only mean he will be introducing that particular vocabulary known as lawyers' jargon, including words such as "heretobefore", "hereafter", "inter alia" and "herein". Rather, I am concerned that the lawyer will take the proceeding and formalize it so that it takes on the trappings and appearance of a court of law. This can only have an intimidating effect upon the other participants in the process. It can, I believe, result in the exclusion of potential testimony which would be of great assistance in evaluating the proposed impact of a development. Finally, it turns the process into an arena of experts, and while there is surely a role for experts, there

is just as an important a role for the layman. The anguish and concern of a parent whose child has been affected by lead contamination is no less pertinent to the tribunal than the data presented by a planner. The observations of a concerned citizen as to smell or noise are of equal importance as the observations of the expert trained in that area, and my concern should be clear therefore that if you formalize the proceedings or"legalize" it as I have suggested, the process will become foreign to people who not only have a right to participate in the process but whose views ought to be heard.

Now having expressed my concerns about the possible effect that lawyers might have on the process, let me turn my attention to the possible domination of the hearings by technical experts including bureaucrats. Allow me to premise my remarks with the following observation.

It has become a truism that regulators tend to reflect the interests and concerns of those they are intended to regulate. This phenomenon is well documented in literature concerning administrative tribunals.and while I impugn no ill motive to the bureaucrat or a civil servant whose task it is to regulate such conduct, I believe that if too much importance is placed upon the strength of expert evidence that the public interest will inevitably suffer. For example, we all know that the National Energy Board, in 1970, when asked to advise the Canadian Government on the reserves available to fulfill future requirements for petroleum and gas, accepted without reservation, the estimates presented to it by industry. Understandably, the

National Energy Board probably believed that it would be foolhardy indeed for industry to attempt to deceive them since they were in a position to regulate industry. Nor do I suggest for a moment that industry purposely deceived them. However, we now know that the estimate of reserves was dramatically overstated and unduly optimistic. The simple point of the matter is that the interest of the National Energy Board and the interest of the companies it regulates were not necessarily the same. Yet for some reason, the National Energy Board became a reflection of the interest of the companies it purported to regulate. While this is a dramatic example of the phenomenon to which I previously alluded, it is by no means special or exceptional.

Experts fulfill a useful role. By virtue of their background and training, they can assist the tribunal in arriving at a proper assessment based upon scientifically valid evidence, but the potentiality for abuse with respect to expert testimony also exists. I think it fair to say that if you have a particular point of view, you can probably find an expert somewhere prepared to testify in support of your contention. Furthermore, my personal opinion of expert testimony is that it is greatly influenced by the views of the person retaining that expert and submitting his testimony. With the cut back in funds available for research generally throughout North America, my concern increases. As governments have cut back the money available for research, industry has increased the amount of money available for research. Many

academics, especially in American universities, depend upon industrial research grants to maintain their positions in the university. I am not for a moment suggesting that they prostitute their principles in order to obtain research money, but I am suggesting that the quality of their expertise becomes tainted when the research is funded in whole or in part by an industry for whom they are expected to become spokesmen.

Private consultants, especially in the environmental area purport to make it very clear that their analysis will be objective and may result in a finding adverse in interest to their client. In my experience, such a possibility is minimal and remote. No doubt, every consulting firm can point with justifiable pride to a report in which they advise the potential client that they do not agree with the environmental soundness of the proposal. Those cases, I would suggest are rare and exceptional and that for the most part, the consultant's report tends to reflect the vested interests of his client.

If the Board is faced with conflicting expert testimony, then the result which they are likely to reach will be a compromise between the opposite positions. Such a compromise is the result of a natural human tendency. If you offend all parties, you have treated them equally. But the environment cannot be adequately protected if decisions are based upon compromise. There are some questions upon which compromise is simply not possible. For example, if the assessment deals with a plant using a radioactive process, and for which

satisfactory safeguards are not in place, then in my view, a compromise with respect to those safeguards is not suitable unless the safeguard establishes conclusively that there will be no harm to workers or surrounding residents. There can be no compromise, in my view, on that position.

Just as a lawyer tends to legalize the process, so the experts attempt to elevate the discussion to the level in which they feel most familiar and in which they are free to use the jargon of their particular expertise.

I make only one observation on the testimony of experts. That is, I have found that the expert who really knows what he is talking about, is able to explain his findings and conclusions in a clear and concise manner and in language understandable to any reasonably intelligent person even though not specifically trained in that area. The so-called expert who relies upon the mumble jumble of his trade and who is incapable of testifying in a manner and using terms which are understandable to the reasonably intelligent layman, is, upon closer reflection, not a real expert in his own area. That rather naive test is always used by me when I size an expert witness up. If, after he has testified, I require the assistance of my own expert to understand his testimony, I am reasonably certain that I can damage his credibility upon cross-examination. Since experts will undoubtedly play a major role in environmental assessment hearing, I gratuitously warn you of my method of evaluation of so-called experts. Kindly bear in mind that free advice is usually worth what you pay for it.

Looking at the Act itself, I might for the moment speak about some of the areas which give me cause for concern and some which are especially laudable.

The Act applies to the activities or proposals in respect of plans or programs proposed by the Province of Ontario or by its public bodies or by municipalities although the municipalities are to be brought into the Act at some time in the future. Also in the future, the scope of the Act will be extended to major commercial or business enterprises in the private sector. I emphasize the use of the words "major commercial", since it will be an interesting question of definition as to the quantitative method of defining what is and what is not a "major enterprise". I would think that the Board itself will have to grapple with this question and that they will be able to propose a test which will be of some assistance to potential proponents. The size of the undertaking is not necessarily the proper test, but the significance of its impact upon the environment, is. I can foresee a very small installation which would have a very significant impact, whereas a very large installation might not. It would, of course, be impossible to have one test which would be suitable for all proposals. Indeed, the flexibility of the present Act, unless abused, is to be preferred to a strict definition of those proposals to which an environmental assessment procedure must be applied.

The assessment procedure should take place at the earliest possible time and indeed, policy decisions or "proposals" should be submitted for assessment before they become specific project oriented. Let me give you an example of an environmental

assessment which took place too late. Imagine if you will, this hypothetical scene. Late in the fiscal year of 1963, a middle-ranked bureaucrat in the Federal Transport Department discovers that by accident, the sum of $25,000 of his department budget remains to be spent. Not content with simply reporting this matter to his superiors, he turns his rather fertile mind to proposing a way in which these monies might be usefully spent. After analyzing all of Canada's transportation needs, he lights upon the idea of studying the potential requirement of a second airport in each of Montreal, Toronto and Vancouver. He promptly dashes off a memorandum to his immediate superior, advising him of the fact that this money was not spent and that it could be usefully exhausted if it were used to fund a group to study the feasibility of these new airports. His idea is rapidly taken up by the Department of Transport and in the ensuing fiscal years, the feasibility study becames in turn, an interdisciplinary study group, interdepartmental task force and finally, an inter-departmental committee with respect to the planning and construction of the new airports. By 1970, the idea which had been borne in 1964 has gathered sufficient momentum so that what was once fancy, becomes fact. Millions of dollars are spent not only to design the project but also to acquire the lands to provide the necessary services. In 1973, the Government announces that it will hold an environmental assessment hearing with respect to the probable effects which this new airport might have upon the environment. With the greatest of respect, the chances for a successful assessment are nil. The assessment, if any,

should have been conducted on the initial decision of the civil servant in 1964. His proposal by the sheer momentum built into the system becomes a steam roller that will flatten any obstacles in its way including the best intentionsof the Environmental Assessment Tribunal.

The environmental assessment itself is discussed in Section 5 of the Act. The proponent must describe the purpose of the undertaking and a description and a statement of the rationale for the undertaking, the alternative method of carrying out the undertaking and the alternatives to the undertaking. Some commentators have suggested that this is an open ended requirement and that if Ontaric Hydro were to propose a new nuclear reactor in Pickering, they would also have to discuss the alternative methods of hydro production including gigantic windmills on the shores of James Bay. Again, I suppose the Assessment Board will have to turn its mind to this question but I would suggest that when one discusses alternative methods of carrying out the undertaking, it would be in the light of reasonable alternative suggestions although I would not be prepared to impose a geographical limit, on the area in which the alternative method must be assessed.

Obviously, when discussing alternative methods, it is possible for the consultant to have a field day and to produce an environmental assessment that is nothing less than an opus magnus. I suspect that all persons involved in this process will after a couple of years develop an expertise in producing environmental assessment studies. In fact, I have seen some done recently which use a literary style which is almost

journalistic and through the proper use of indexing and cross referencing, can condense the most substantial material into a reasonable number of pages. Then, if the authors wish to cite any reference books, they can always do so in an appendix.

The Environmental Assessment document must also describe the environment which will be affected or that might reasonably be expected to be affected directly or indirectly including the effects that will be caused and the action necessary to prevent, change, mitigate or remedy the effects that might reasonably be expected upon the environment. Finally, there must be an evaluation of the advantages and disadvantages to the environment of the undertaking, including the alternative methods of carrying out the undertaking and the alternatives to the undertaking. While this might sound like a very difficult and perhaps wasteful requirement, I would suggest that upon closer scrutiny, it is no more than what one would expect from a careful, objective scientist. The point of the matter is that no developer would think about building a major development without a complete analysis of the cost of the project, the cost of the land and the financing and development cost. Nor would he proceed without a proper cash flow statement so that he would be able to advise his financiers of the return upon investment. Further, no developer would start his project unless he was reasonably certain of the fact that he was complying with the various requirements of the municipality, the Planning Act and other government agencies. If he did anything other than that, he would be foolhardy.

The requirement of Section 5 of the Environmental Assessment Act is to require that the proponent also turn his mind to the environmental changes that his proposal is likely to affect. This is a reasonable and proper demand, for just as the developer must assess the cost to him of the development, so must society assess the cost to it of the development. There are certain developments, I trust the majority of them, which we will see fit to incorporate into our environment. In other words, the benefits of those developments far outweigh the costs.

Inherent in this suggestion is that no person acquires the right to affect the natural environment of the Province of Ontario merely as a result of owning land. This right, if it ever existed, has been prescribed severely by our laws. For example, the kind of building which you are permitted to erect, may be limited by by-laws. The height and design of the building is limited by by-law. The kinds of uses which you might make of your land are limited by various planning regulations. The fact that you cannot use your land if the usage results in an obnoxious or harmful emission has been well prescribed. This concept however, did receive a minor setback when the Rockcliffe Park case was recently decided by the Court of Appeal. There, one of the Judges, Mr. Justice Dubin, suggested in his Reasons for Judgment that as long as the activity which was being impugned was limited to the private lands of the owner, that the Environmental Protect Act did not apply. Mr. Justice Dubin, with the greatest of respect, failed to recognize the fact that

the environment is the public's domain and private ownership cannot give any owner private rights to damage or despoil the environment.

When talking about the requirements of the environmental assessment itself, I would suggest that the main onus for brevity and clarity will rest upon the officials of the ministries of the Province of Ontario making the proposal. Since the initial assessment procedures will only affect proposals of the Province of Ontario, I would suggest that those who are engaged in the writing of the assessment, without limiting their concerns, direct their minds to brevity and conciseness.

I must necessarily deal with the issue of aesthetics. Some of you may like concrete buildings, while others like large stainless steel buildings. Some of those who work for Hydro like large mirrored buildings. To sit in judgment on the matter of aesthetics is to enter upon a path fraught with danger. However, I see no alternative. At some stage, visual pollution or aesthetics is no less important than the other technical or environmental aspects of the proposal. I quite frankly cannot assist the Board as to guidelines in that respect and I foresee some difficulty ahead in questions relating to this problem.

In the event that neither the Minister nor any other person requires a hearing, it would be possible for the Minister, after receipt of the environmental assessment, and after completion of a review of that assessment by his staff, to

accept or reject the proposal as submitted. That would be the end of the matter insofar as the proponent is concerned.

However, in the other cases, i.e., where the Minister requires the environmental hearing or a person by written notice to the Minister requires a hearing, then the Board shall hold the hearing with respect to the acceptance or amendment of that assessment.

Now having said that, I should point out that the Minister can exercise his absolute discretion and deny a hearing to a person who requests the hearing, if the Minister considers that the request is frivolous or vexatious or that a hearing is unnecessary or may cause undue delay. I am not overly concerned by this discretionary right of the Minister since I believe that he would be governed in his actions by not only what is proper but also what is politically expedient. I believe that a Minister would not stay in office very long if he were to abuse the discretionary power to absolve from review a proposal which had a significant impact on the environment.

I do have some concern, however, about the potential problems related to the use of the term "undue delay" in terms of the Minister's discretion. There is a legitimate concern with respect to the initial delay of environmental assessment. No doubt, the private proponent will be sitting with expensive land having spent a considerable amount of money not only to design the project but also to evaluate it from an environmental point of view. This can only serve to increase his rather

considerable development cost. Lamentable as that might be, it will have to be accepted as a fact of business life. One thing is clear. Undue delay is not to be tolerated. Delay is inevitable. Increased lead time will have to be planned in respect of his new developments. This has happened in the past. For example, when The Planning Act was introduced, developers and lawyers screamed that the additional requirements of complying with The Planning Act would render new development impossible. It is interesting to read the earlier cases and articles and to hear the same complaints being voiced today about the Environmental Assessment Act. My concern is therefore that while I acknowledge the absolute need of expediency, I am concerned that legitimate views could be sacrificed in the name of expediency. I am not convinced based on the experience in other jurisdictions that this assessment procedure results in undue delay but it will undoubtedly result in some additional delay.

The last step in the procedure will, of course, be the hearing. Since there has not to date been any real experience with assessment hearings in Ontario, it is foolish to hypothetisize about the content or form of such hearing. I have already spoken about my concerns with respect to the involvement of lawyers and experts. The tribunal will only be successful if the public has credence in the legitimacy of the hearing process. The tribunal must at all times be the master of its own process. It must never let the conduct of the hearing fall into the hands of the counsel for any of the interested parties.

While debate should not be stifled, it is proper and legitimate for the Hearing Board to direct the parties to make submissions on limited points. While the strict rules of evidence should not be applied, the tribunal should not allow witnesses or counsel to roam freely and at will in their testimony and presentation of evidence. The tribunal will develop an expertise of its own. In short order, they will know what is credible and what is not. While becoming experts in their own right, they must never foreclose their minds to the submissions of the parties. The tribunal must be patient with the inarticulate and without condescension for the emotional. Unless all parties involved believe that they have received a fair hearing and believe that they have had a full and proper opportunity to present their views, then the process itself cannot succeed. One of the hallmarks of recent years has been the loss by the populace of its confidence in its selected representatives. This has been a function of many factors, but above all, it is a function of the perceived refusal of our legislators to heed our views. Government has become callous and that callousness reflects itself in the population. This Hearing Board, following the example of the Berger Commission, must always appear to be interested and attentive. They must be sympathetic, fair, but firmly in control at all times. Anything less, will dissipate the confidence required to uphold the process.

In answer to the question raised in the title of this paper, I don't think that an environmental impact assessment

will be the nightmare of industry as suggested by some industrial spokesman. Potential for abuse is present. From my experience and based on the experience in other jurisdictions, such abuse is unlikely to occur. As for lawyers, I suppose that it is inevitable that they will get their fingers into the cookie jar. As a profession, we seem to have had remarkable success in convincing people that they ought not to speak their minds without the advice of counsel. While it is a development with which I am not entirely in accord, I see no fruitful purpose in tilting at windmills.

Lawyers' involvement is inevitable but the extent of their involvement can be controlled. Let's remember what this Act is about. It is about the betterment of the people of Ontario. The expertise to arrive at that decision lies within all of us. As concerned citizens, parents and observers, even untrained, we have a legitimate and rightful role to play in that process. This system must work. The quality of the environment is too important an issue to allow the decision in respect of the quality of the environment to be determined by a handful.

Ladies and gentlemen, I thank you for your prompt attention. Notwithstanding my comments about lawyers in the environmental assessment procedure, I know that they will be present and I hope that I am fortunate enough to be retained on some of them. Give your testimony in a straightforward and concise manner and I promise that your cross-examination will be a painless experience.

A REVIEW OF METEOROLOGICALLY BASED SUPPLEMENTARY EMISSION CONTROL SYSTEMS

The maintenance of air quality standards is of major concern to industry. Hundreds of millions of dollars have been spent on various control techniques. Tall chimneys and acid plants are the most commonly used methods in the mining and smelting industry. Both these techniques are costly and while they do reduce the frequency of specified ground level concentrations, they cannot under all meteorological conditions eliminate ground level concentrations.

Certain combinations of meteorological phenomena generally control the level of air quality related to a specified source or from multiple sources in combination.

Supplementary emission control systems which are reviewed in this paper are being given more consideration and in some places are accepted as a means, in conjunction with less costly scrubbing systems and chimneys of moderate height, of maintaining specified air quality standards and keeping both capital costs and maintenance costs at a minimum.

by

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A REVIEW OF METEOROLOGICALLY BASED SUPPLEMENTARY EMISSION CONTROL SYSTEMS

by

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The Supplementary Control System (SCS) or use of intermittent control, is not a new concept but a logical engineering and economic approach that has been used for some time to meet ambient air quality standards. Such systems are in use not only in the U.S. and Canada but also in other countries. Table 1 presents a list of locations where some form of intermittent control is presently in use.

While most applications of the SCS are directed to the control of SO_2 they can be just as easily used to control other pollutants.

Supplementary Control Systems are quite attractive to operators of large isolated point sources of SO_2 when comparative costs are made between the SCS and installing and maintaining sophisticated SO_2 scrubbing equipment. In a recent paper by Montgomery and Frey (1975) of the TVA, they state that the "average development and operational costs for an operational SCS are \$0.581 and .232 million. In contrast, based upon the estimated cost of the single experimental SO_2 scrubber for the Widows Creek unit 8, it might cost <u>\$100 million to equip a large power plant with SO_2 scrubbers and another \$20 million per year to operate it"</u>. Even with such scrubbers there is no guarantee that ambient standards can be maintained under all meteorological conditions.

TABLE 1

COMPANIES USING SOME FORM OF INTERMITTENT CONTROL

CANADA	U.S.	OTHER
Cominco	ASARCO (5) locations	Mt. Isa Mining (Australia)
INCO	Bunker Hill	
	Kennecott Copper	
	Magma Copper Co.	
	Phelps Dodge Corp. (2)	
New Brunswick Electric & Power Company	Central Illinois Light Co.	Electricity du France
Ontario Hydro	Commonwealth Edison Co.	Italian Energy Co.
	Dow Chemical	
	TVA (9)	

There are generally two types of intermittent control procedures. One is referred to as a feedback loop (closed loop system) presently being used by the American Smelting and Refining Company in El Paso, Texas. With a feedback loop action is only taken after the monitor indicates the beginning of an SO_2 excursion. The SO_2 readings are fed back automatically to the control room where the operator assesses the reading and then takes appropriate action. The other is referred to as active control which is based on a forecast of ground level concentration and involves the prediction of pertinent synoptic and local meteorological parameters for insertion into a diffusion model. Emission reduction can then be planned well in advance by the operator. The latter is used by the MEP Company in Toronto and applied to plants in two different locations in Canada. These are presently undergoing experimental evaluation. The TVA have been using an operational active control loop in their Paradise Plant since 1969. The sucess with this initial program (see Table 2) has led to the development of similar systems for several of their other plants. According to Montgomery et al (1975), TVA consider such programs to be the most effective way to meet both primary and secondary SO_2 ambient standards. Figure 1 shows, schematically, a typical active control system such as MEP uses. It is also somewhat similar to that of the TVA.

Ontario Hydro uses a supplementary control system (Active Control) to

Table 2

24-Hour Average SO_2 Conc. Range* (ppm)	Frequency Before (4/29/63-9/18/69)	After (9/19/69-3/31/74)
0	8,232	7,611
.001 - .02	6,052	6,752
.021 - .04	549	496
.041 - .06	121	110
.061 - .08	29	27
.081 - .10	14	11
.101 - .12	7	5
.121 - .14**	4	4
.141 - .16	7	0
.161 - .18	1	0

*From four SO_2 recorders 1963, and 1964; increased to five SO_2 recorders on April 20, 1965; increased to fourteen SO_2 recorders on January 1, 1968; reduced to seven SO_2 recorders on July 1, 1971; increased to nine SO_2 recorders on January 1, 1974.

**National Primary Ambient Air Quality Standard for SO_2 is 0.14 ppm, not to be exceeded more than once per year.

Table 5. Frequency distribution of measured SO_2 concentrations before and after implementation of SO_2 emission limitation program at Paradise coal-fired power plant

(From Montgomery and Frey (1975))

switch from a high to a lower sulphur fuel when forecast of high air pollution are issued. A paper by McAdie andGillies (1973) describes the use of a meteorological based control model for industry in Sarnia, Ontario. They state that:

> "the performance of this program indicates that meteorological forecasts can be used successfully to provide major sources with advance information to effect any additional control measures relevant to their individual operations".

The SCS will only work, however, for facilities where emissions and stack heights are such, that the frequency with which ground level concentrations are above a specified level, are infrequent enough that intermittent plant curtailment would not be uneconomical. It is for this reason, that prior to implementing and intermittent control system, an appropriate economic study be carried out to relate the frequency that specified ground level concentrations could be exceeded with differing chimney heights and with varying degrees of scrubbing.

THE MEP SUPPLEMENTARY CONTROL SYSTEM

As shown in Figure 1, the system is divided into several parts which when connected forms a closed loop. Emissions which are released into the atmosphere are controlled initially by plant parameters such as temperature, volume of gas, stack height and building configuration. Onece released into the atmosphere, meteorological parameters control the levels of SO_2 recorded at the monitors. The air quality reading along with local meteorological information are fed back into a data

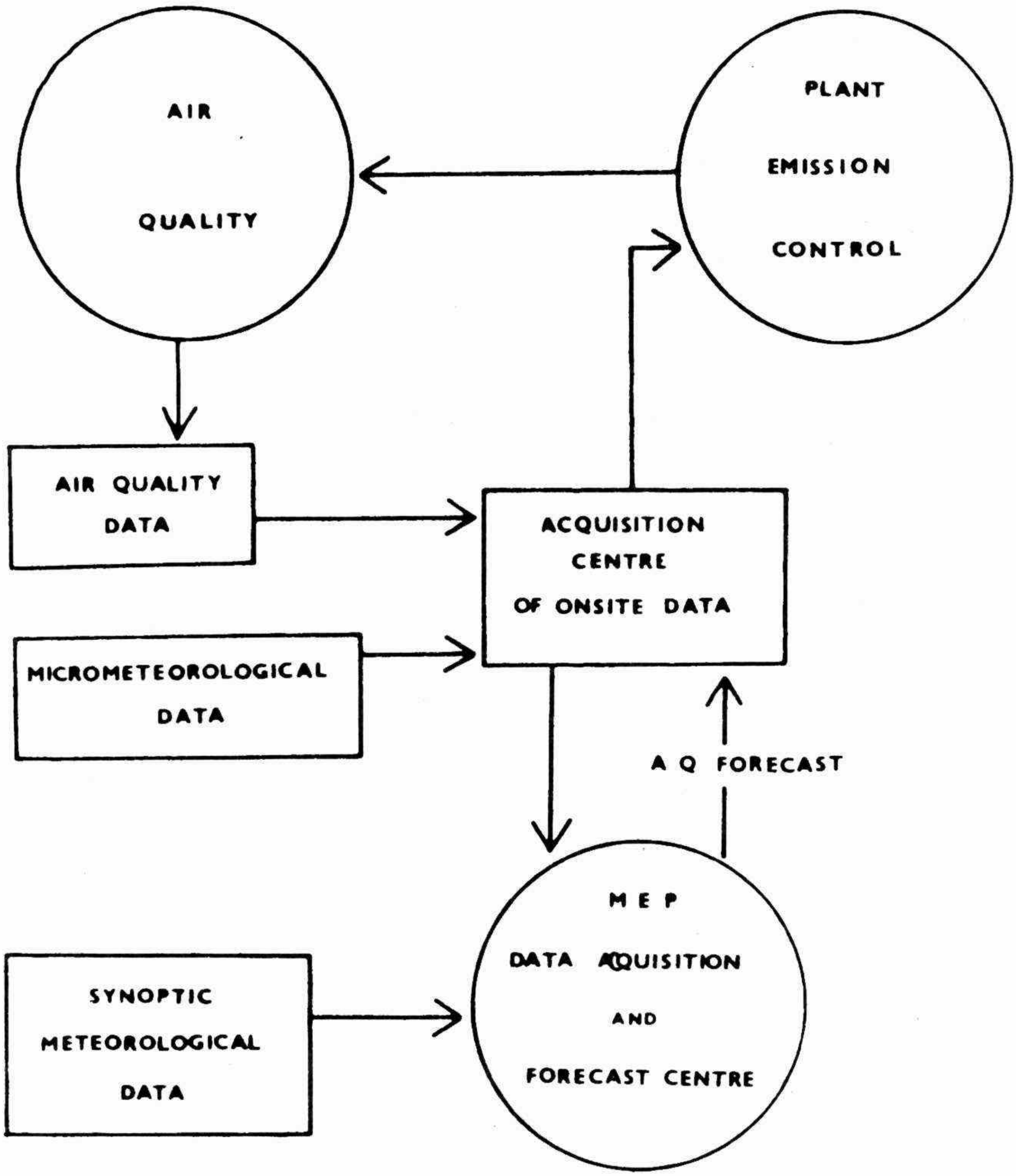


Figure 1. Flow Chart showng typical active control system used by MEP

acquisition center. This information is in turn displayed in both the operations control room and in the MEP forecast office in real time. MEP uses this information along with large scale synoptic data to prepare forecasts for the appropriate facility. Forecasts are usually issued 24 hours ahead as an outlook, then updated every 6 and 12 hours or more frequently when necessary. Where possible, servicing of production equipment can be postponed or updated to coincide with periods of potentially high air pollution.

There is a basic criteria for any facility that must be determined prior to proceeding with the development of an SCS. That criteria is whether or not such a system would be economically feasible. This then implies the following approach.

1. Determine the local controls on dispersion and their interaction with large scale meteorological processes.
2. Determine the frequency with which specified meteorological parameters occur.
3. Proceed with the development of a model which can incorporate the local topography and resulting local turbulence and flow patterns.

Two and three above along with data concerning plant emission parameters are required to determine the economic feasibility of using intermittent control as applied to a specific source. It is obvious that if cutbacks

are expected to occur, say 50% of the time, management would be very reluctant to consider the use of the SCS as an economical means for maintaining ambient air quality objectives. If cutbacks, on the other hand, of 10 to 12% of the time or less could maintain air quality objectives, management may view such an approach quite favourably in lieu of a 100 million dollar expenditure on capital equipment and scrubber operating costs in the order of 20 million dollars annually. If intermittent controls appear feasible the fourth step is taken.

4. Initiate a 6 to 12 month program to familiarize plant personnel with the system and to make final model refinements.

Ambient Air Standards vs Emission Standard

Considerable controversy has been taking place with regard to the use of Emission standards. In some circles the use of the SCS and tall stacks have been opposed on the basis that they rely on the assimilative capacity of the atmosphere and do not substantially reduce total emissions, and that secondary processes may contribute to effects not presently known. In this regard a review paper written by Dr. R. E. Munn for the Science Council of Canada in 1971 makes the following comments:

> "...the implementation of national or international emission standards cannot guarantee that ambient concentrations will never exceed any pre-assigned level. At best, they serve

to distribute equitably the cost of reduction of regionally averaged levels of contamination, and to eliminate pollution havens".

"...the permissible rate of release of pollutants into the atmosphere should preferably be a function of the number of and heights of emitters and of local meteorological and topographical conditions".

"...National and International air quality criteria, on the other hand, make sense because they are related to effect".

The Environmental Protection Agency in the September 1973 entry in the Federal Register (1) (Ref. No. 1) state that:

"The mechanism of the formation of acid rain; the long term effect of acid moisture on plants, materials and soils; and the concentrations of sulphur dioxide that can result in the formation of rain of sufficient acidity to be a danger to the environment currently are being investigated throughout the world. The data needed for standard setting are not now available. Furthermore, it is not clear that acid rain would be a problem following attainment of the National Primary Standard for sulphur dioxide".

The EPA in their discussion concerning the proposed change in regulations to accommodate the supplementary control system state that: (1973)

> "many existing nonferrous smelters would require emission reductions in excess of 90 percent in order to avoid violations of the national standard sulphur dioxide during all adverse meteorological conditions. Constant emission limitation techniques capable of achieving this degree of emission reduction are not available for every smelter. The alternatives in most cases, will be either to close these facilities (or drastically curtail production), or apply supplementary control systems".

MEP AIR QUALITY FORECAST EXPERIENCE

A twelve month test and evaluation program of the MEP SCS was carried out for a point source of atmospheric emissions in Quebec. Forecasts of excessive SO_2 ground level concentrations were issued whenever they were expected to occur at a monitor site (five sites in all). In addition, the maximum ground level concentration was forecast along with its down-wind location whether or not it was expected to occur at a monitor. A typical forecast that might be issued via telex is reproduced below.

Wednesday Sep 3 0740 EST
Attn: J. Doe

AQ FCST Vld 0800 - 2000 EST

Ridge of high pressure crossing area during day. Wind light north'ly this morning becoming south'ly this afternoon.
P2 P4 T2 - 0.1 - 0.3 ppm with 2 - 3 hours 0.3 - 0.6ppm.
between 0800 and 1200 EST then becoming 0.1 ppm or less after 1500 EST
P3 - 0.1 ppm or less with 2 - 3 hours 0.3 - 0.6ppm between 1500 and 2000 EST

Max conc 0.4 - 1.0ppm at 2 - 12 km to south until about 1200 EST then variable and then to north after about 1500 EST

End (note: P1, P2, P4, T2 and P3 are SO_2 Monitoring locations)

A ridgid scoring technique of the forecast was used. There were only two categories, an accurate or inaccurate forecast. If, for example, a one hour excursion above a specified limit was forecast but not recorded at a monitor the forecast was listed as inaccurate even though SO_2 fumes may have just missed the monitor. In logging the forecast score for such an incident, the statistics would record this as a wrong forecast for an interval of three hours. This was necessary since it was assumed that the plant would reduce its emissions one hour prior to the forecast time and again start up one hour after the end of the forecast excursion.

Figure 2 summarizes the test and evaluation period (May 1974 to September 1975). The pie representing 100% of the forecast hours was divided into the following categories: SO_2 correctly predicted to remain below .34 ppm; SO_2 correctly predicted to be above .34pp;

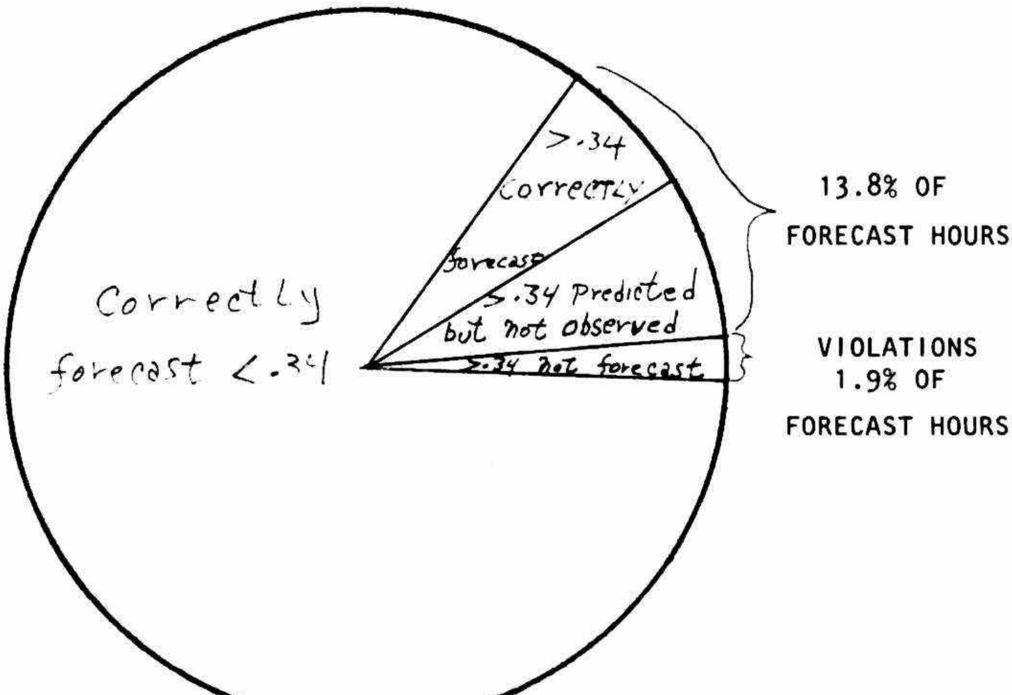
predictions of SO_2 greater than .34 ppm but not recorded at a monitor; and SO_2 recorded above .34 ppm with no predictions of SO_2 above .34 ppm.

To keep the cost of the experimental program to a minimum, the evaluation period was based on a five day week with each day covering the period from 0900 to 2100 hours. This coverage was thought to be sufficient for statistical purposes. Previous studies indicated that night-time SO_2 excursions were quite infrequent.

For the evaluation period the division of the pie would indicate that strict adherence to air quality forecasts and with approximately 50% emission reduction during forecast excursions, the plant would lose approximately 50% of its production capacity over 13.8% of the forecast hours. A violation however, would have occured for 1.9% of the hours. This is in contrast to 15.7% of the forecast hours without intermittent control. During these forecasts it was assumed that all emissions were from an elevated chimney and none from low level vents. (This was not strictly the case.)

The above described the initial results of implementing an SCS for a location in Quebec. A similar system has been developed for a location several kilometers inland from one of the Great Lakes. The system has been in operation since early spring 1976 and as a result no formal statistics are presently available. Since April, however, and until

Figure 2. COMPARISON OF AIR QUALITY FORECASTS WITH ACTUAL MONITOR RECORDS FOR THE PERIOD FROM MAY 1974 TO SEPTEMBER 1975.



BASED ON THE ABOVE, AND IF THE SUPPLEMENTARY CONTROL SYSTEM WERE OPERATIONAL DURING THIS PERIOD, THERE WOULD HAVE BEEN APPROXIMATELY 50% PRODUCTION CUT BACK FOR 13.8% OF THE FORECAST HOURS. 1.9% OF THE FORECAST HOURS WOULD HAVE A VIOLATION AND 84.3% OF THE TIME FORECASTS OF NO VIOLATIONS WITH EMISSIONS UNDER NORMAL OPERATIONS PROVED VALID

June 1st only two excursions occurred out of a possible 15 and these as a result of emission cutbacks not initiated soon enough.

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THE CONTROL OF HYDROGEN SULPHIDE EMISSIONS
at
ONTARIO HYDRO'S BRUCE HEAVY WATER PLANT

Ontario Hydro's Bruce Heavy Water Plant A is a 250 million dollar chemical plant located at Douglas Point on Lake Huron. Its primary process uses hydrogen sulphide to extract deuterium from natural water.

Hydrogen sulphide emissions to air are extremely obnoxious to humans and can occur from minor leaks and from unburned releases from the flare. It burns to sulphur dioxide which can also be environmentally undesirable. This paper describes how hydrogen sulphide emissions to air and the resultant odours are minimized.

Hydrogen sulphide must be stripped from water streams which are returned to Lake Huron. Such emissions could result from process upsets and from equipment malfunctions. The paper describes how hydrogen sulphide releases to water are being minimized.

Effective monitoring and process and facility changes all have played a role in making the environmental program a success. Future plans are outlined.

by

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THE CONTROL OF HYDROGEN SULPHIDE EMISSIONS

AT ONTARIO HYDRO'S BRUCE HEAVY WATER PLANT

by

STAN A. C. FRANKLIN
KEN R. BISHOP

The Bruce Heavy Water Plant is a billion dollar chemical plant located at the Bruce Nuclear Power Development on Lake Huron. Its primary purpose is to extract and concentrate heavy water from Lake Huron for use in Canadian reactors of the CANDU (Canadian Deuterium Uranium) design. The first plant, Plant A, went into service in 1973. Plants B and D are now under construction. The main process operation uses hydrogen sulphide (H_2S) to extract deuterium oxide or heavy water from natural water. One Mg/s (megagram per second) of process water and 9 Mg/s of cooling water are pumped for Plant A.

Before discussing the environmental considerations in detail, a brief description of the plant would be useful.

Slide #1 shows the process water primary flows. After water is pumped from Lake Huron, it passes through a clarifier and filters and is then degassed of oxygen and carbon dioxide. Before entering the extraction stage, the water is partially saturated with H_2S, and unabsorbed gases are purged. In the extraction stage, hydrogen sulphide gas contacts cool water at 30°C and deuterium atoms concentrate in the liquid phase. When the temperature is raised to 130°C a portion of the deuterium transfers to the hydrogen sulphide gas. By transferring enriched streams to successive stages and repeating the bithermal process, the deuterium concentration is increased.

Before the deuterium depleted water is returned to Lake Huron, the H_2S must be removed from it. The key operation occurs in the effluent water stripper where H_2S is stripped from the water and recycled. The water is then returned to the lake, or if not within the limits for H_2S concentration, the return may be delayed by passing it through effluent lagoons.

Slide #2 shows Plants A, B and D which make up the Bruce Heavy Water Plant. Using Plant A as an example, the following facilities can be identified:

Water Intake

Pumphouse

Degasser

H_2S Absorber, Purge Tower Area

Extraction Tower

Effluent Water Stripper

Effluent Lagoons and Outfall.

To focus on the first of the two environmental aspects to be presented in this paper, H_2S emissions to air will be described.

H_2S-IN-AIR

Hydrogen sulphide is an odourous material. If concentrations reach more than 200 $\mu g/m^3$ (micrograms per metre cubed) H_2S can be smelled by most people. As well, H_2S is considered by virtually all humans to have an unacceptable smell.

Although the Bruce Heavy Water Plant is built on a large scale, it is a rather ordinary chemical plant. Normal operation can cause releases of H_2S to the atmosphere.

Plant operations will be dealt with more specifically later, but first the H_2S-in-air problem will be defined from the point of view of the local residents. The Bruce Heavy Water Plant is located in an area bounded by cottages to the north and south. When H_2S odours became a nuisance in 1973, owners pointed out that most of their cottages were built 10 to 20 years ago. People left the cities during their vacations to escape the smells of the cities and, until the Bruce Heavy Water Plant was built, the air at their cottages was as sweet as a lakeshore air can be. Thus the scene was set for a real environmental problem.

Although serious consideration had been given to environmental matters, the real meaning of environmental control was yet to be faced. Complaints of odours started to be received shortly after H_2S was introduced into the units in 1973. By year end, a total of 56 complaints were registered in the Bruce Heavy Water Plant control room. Citizens also registered complaints with the Ministry of the Environment and a local "Committee of Concern" was formed. It is an exaggeration to say that the community was in an uproar, but it can be said that the Bruce Heavy Water Plant's image with the public was less than satisfactory.

Clearly, extraordinary measures were necessary to rectify an unsatisfactory situation. In response, Plant Management established a small group to resolve the environmental problems. The group had the nature of a task force and was goal oriented. As the program evolved their activities included the following:

1. Monitoring of day-to-day environmental performance.

2. Identifying all equipment that caused H_2S releases.

3. Establishing environmental objectives.

4. Initiating action to make improvements:

   - equipment changes
   - operating procedure changes

5. Referring detailed engineering to project groups so that full attention could be paid to the problem by the environmental group.

6. Monitoring the effectiveness of equipment changes and rectifying them as required.

7. Auditing the day-to-day operation from an operations point of view and providing feedback to production supervision.

8. Establishing training programs to increase operators' ability to control the equipment from an environmental point of view.

9. Recording and publishing data to reinforce environmental performance improvements.

10. Establishing an employee reporter system to improve knowledge of releases.

With such a task force and full management commitment, the problems soon began to be defined and soon yielded to solutions. The result of the task force was the development of a program to deal with the H_2S-in-air problems. This program was discussed with the Ministry of the Environment and was given their approval. The program was modified by mutual agreement as problems were defined and action initiated. For example, an incinerator was envisaged as part of the program, but was later deleted when alternate solutions to incinerating H_2S were found. Progress was reported and reviewed regularly with the Ministry of the Environment on a flexible and cooperative basis. The following sections describe most of the problems encountered and the corrective action that was taken.

The schematics in this slide (Slide #3) present a typical enriching unit tower as it is connected to the flare system. These connections are required to protect the unit from overpressure and to exhaust H_2S from equipment for maintenance purposes. For example, pumps are drained to the process drain header. The H_2S saturated water is conducted to the process drain tank, where the H_2S flashes off to the flare. H_2S in towers is normally run down to storage but the final depressurization and purging is done to the flare header.

Finally, the flare tip is fitted with a ring of burners to ignite H_2S as it is released. The reason for burning the H_2S is to convert it to SO_2. Slide #4 shows the reaction:

$$2\ H_2S\ +\ 3\ O_2 \longrightarrow 2\ H_2O\ +\ 2\ SO_2$$

SO_2 is less toxic than H_2S and cannot be smelled below 8000 $\mu g/m^3$ (micrograms per metre cubed). This compares, as stated previously, with 200 $\mu g/m^3$ of H_2S being detectable.

The flare stack (Slide #5) is 135 m (metres) high. It is built to this elevation so that releases will disperse before reaching the ground. As well, heat from burning the H_2S causes a further elevation of gases for greater dispersal.

Considering the usual chemical plant facility, this system appeared to be more than adequate and little trouble was anticipated. Nevertheless, complaints of odour began to come in and the first job of the environment group was to find out why. H_2S-in-air monitors to measure in the 0 - 350 $\mu g/m^3$ range were installed in areas adjacent to the plant and survey crews were sent out to determine which gas people were reporting. It was determined that the odours were caused by H_2S. This meant that H_2S was escaping from the flare stack unburned. Pilot igniters were checked and found to be functioning properly.

Another phenomenon encountered was that H_2S was detected close to the plant (as close as 450 m from the flare stack) as well as up to 30 km (kilometers) away. This implied that sometimes the H_2S was not being carried far away, and if it was, the gas wasn't dispersing as expected.

After consulting Ontario Hydro's meteorological branch the reasons were identified (Slide #6). Many fair summer days were characterized by very low wind velocities in the early morning. As the sun heated the land, cold stable air was drawn in off Lake Huron over warm unstable air. H_2S was emitted into this stable air and travelled in a concentrated form until it contacted the unstable air. At this point, the H_2S was conducted to the ground and was easily smelled. From then on, of course, good mixing occurred and the H_2S became so dilute that it could not be detected farther downwind. At cottage areas near the plant concentrations up to 450 $\mu g/m^3$ were recorded.

Distant odour complaints could also be explained (Slide #7). In some cases, with slightly higher wind velocities, early morning releases would travel out over Lake Huron, within 15 degrees of the shore, in cold stable air. The air over the lake was so stable that no mixing occurred. As the sun heated the land, the wind direction changed and the plume of H_2S was drawn over the land. Since H_2S is slightly heavier than air and the gas stream was at a low elevation it descended and could easily be smelled when it reached the land.

The conclusion of this study was that although the flare stack was well designed from a height point of view, local weather conditions allowed the unburned H_2S to reach ground. Although basic, this was a significant step forward.

Clearly, the matter that had to be resolved was why H_2S was escaping unburned. The resolution of this problem can be understood after some typical operations are explained (Slide #8).

Operation of the process drain tank was part of the problem. As water, saturated with H_2S from a higher pressure was drained into the tank, H_2S flashed off to the flare. But the water which was still saturated at atmospheric pressure accumulated in the tank. Eventually (Slide #9) the water in the process drain tank had to be sweetened and released to Lake Huron. The sour water was pumped through an intermittent stripper and the liberated H_2S was conducted along with the steam to the flare stack. The flare stack gas makeup was then investigated. The question to be resolved was whether the stack gas would be likely to burn when it contained considerable

water vapour.

This slide (Slide #10) indicates the key to the problem. It was determined that if the stack gas had a net heat content of less than 3700 J/kg (joules per kilogram) then combustion at the flare tip would be unstable. Typical stack mixtures were 90% steam and 10% H_2S. It can be seen that this gas has a much lower heat content than required. This slide will be referred to later.

When the steam problem was identified resolution of the problem was begun. First of all, (Slide #11), efforts were directed toward reducing the amount of H_2S released on the assumption that if H_2S was not released, it would not be smelled.

Secondly, (Slide #12), steps were taken to increase the heat content of the stack gas. As can be seen in Slide #13, if the ratio of combustibles is increased to 80% propane by volume, the heat of combustion of even a 90% steam mixture can be increased to greater than 3700 J/kg. That is if the stack gas consists of 8% propane, 2% H_2S plus 90% steam, the mixture will burn. Propane was added to the bottom of the flare stack with significant results.

Thirdly, steps were taken to conduct water from the process drain tank back into the process instead of to the intermittent stripper. This increased the heat content in the stack gas by decreasing the water vapour content.

Other efforts complemented these three activities. During preparation for tower entry or equipment maintenance, efforts were made to promote H_2S recovery and to ensure that any operation which injected or released steam to the flare was preceded by injecting propane into the flare stack. Intermittent purging of nitrogen and other inerts from the enriching units was also accompanied by increased propane flows to the flare. Small amounts of propane were constantly kept flowing to the flare to ensure chronic small scale leaks of H_2S were well incinerated.

Concurrent with these technical activities, it was necessary to address the operation aspects of the problem.

Plant Management (Slide #14) established the environment priority second only to safety, but ahead of production priorities. Rigid adherence has been given to this priority system.

Secondly, (Slide #15), it was important to increase operator awareness of the problems and their solutions. A training program was established in 1974 and repeated annually. As indicated previously, day-to-day environment performance was monitored and lessons learned from operating experience were fed back to supervisors for future application.

The results of this program showed considerable improvement (Slide #16). In 1973, 56 complaints of odour were received from the public. In 1974, 3 reports came in. In 1975, only 4 reports of odour were received. Relations with the public are no longer a problem as far as H_2S odours are concerned.

In conjunction with tripling the capacity of the plant, an H_2S recovery system to minimize H_2S and propane usage is planned. See Slide #17. This system includes additional facilities to permit H_2S recovery from various sources, such as: chronic losses, process purging and equipment depressuring. The results will be that H_2S releases to the flare will be further reduced.

As shown on Slide #18, the Bruce Heavy Water Plant air environment objectives can be summarized as:

1. Reduce emissions of H_2S to the flare stack.

2. Maintain a high heat content of stack gas for efficient combustion.

3. Recirculate waste H_2S back into the process system.

From a management point of view, the policy is that:

1. Environment priority is second only to safety.

2. Operator awareness must be maintained through training and performance monitoring.

H_2S-IN-WATER

We now focus on the second environmental topic, the emission of H_2S to water. All water streams containing H_2S are stripped of it before the water is returned to the lake. Process effluent is stripped in the effluent stripper; intermittent flushing water is stripped in the intermittent stripper. Both strippers discharge their effluent to a common line which can be diverted to lagoons if required. The topic H_2S-in-water can be understood by examining the causes of H_2S release, the actions that have been taken and the resultant improvements.

Slide #19 shows the causes of H_2S releases to water by year. A variety of means were used to solve these problems. Unstable flows in the towers were quite frequent in 1973. This instability frequently caused the effluent stripper operating conditions to fluctuate. The effluent stripper requires steady flows, pressures and temperatures to effectively remove H_2S. One important physical change, made in 1973, was lowering sieve plate weirs from 100 mm to 37 mm in the extraction towers. Also in 1973, an antifoam was added to the process water to minimize unstable flows in the towers. Steady operating conditions and therefore more effective stripper

operation was achieved. Some recurrent instrument failures have also been eliminated by improving the stripper's instrumentation. Better process control during shutdowns and startups has also contributed significantly to achieving steady operations.

As outlined previously, the process drain tank collects water generated during flushing for maintenance and from small internal leaks. In 1975, facility changes were made to return this water to the enriching units. In 1976, the intermittent stripper has not been used. Since this sour water was often enriched in deuterium, some economic advantages have been achieved by recovering the deuterium.

The remaining causes of release of H_2S to water have been comparatively minor and non-recurrent.

The concern that H_2S might be released to the lake with the plant effluent was anticipated in the original plant design. In order to prevent this from happening, two lagoons were built. The design basis estimated a 3 hour retention time as the effluent flowed through the lagoon. Aeration of the lagoon contents was designed to oxidize residual H_2S to harmless forms of sulphur which would precipitate out of the liquid.

Two problems developed. First, the warm effluent entering the lagoons tended to short circuit across the top of the cooler water in the lagoons and then out in approximately one-half hour. Secondly, aeration proved less effective than calculated.

An operating change was made so that one lagoon was normally empty, and the effluent normally passed through the other full lagoon. When an upset occurred, the effluent was switched to the empty lagoon which had a capacity for 3 hours of plant effluent. Thus the design intent was achieved. Usually upsets were corrected within one-half hour.

What are the environmental standards related to control of H_2S to water? (Slide #20A). Ontario Hydro uses the acronym WHEPP (Hydrogen Sulphide in Water Environmental Protection Performance) to define environmental performance trends.

As shown in Slide #20B, WHEPP is based on the average concentration in the effluent. The WHEPP formula is derived such that 90% is considered by the Nuclear Generation Division to be good performance for a plant. It is shown graphically on Slide #20C along with 1976 performance.

Slide #21 shows the Bruce Heavy Water Plant's past performance. The annual number of releases has been reduced by a factor of 4. The 1976 target for WHEPP is 95%.

Slide #22 shows the main effluent water flows as they exist at present. The two new lagoons which were designed to serve Plants A, B and D are now in use with Plant A effluent. The advantage of this mode of operation is that effluent normally flows back to the lake without passing through lagoons which are empty to provide a 6 hour retention time when needed. Two important innovations were implemented to achieve this mode of operation.

First, the effluent stripper process parameters of feed temperature, level and pressure were interlocked to automatically divert the effluent to the lagoon if the measured variables exceeded defined limits.

A second essential plant improvement was to obtain and install an H_2S-in-water monitor which was highly reliable and had a fast response time of seconds versus minutes for previous monitors. A commercially available H_2S-in-air monitor was used. See Slide #23. In this development air is used to strip the H_2S from the water and a solid state H_2S-in-air detector senses the H_2S. In order to minimize the time needed for a sour sample to reach the monitor, it was physically mounted on a platform beside the effluent stripper. As installed it has proven reliable, quick to respond and inexpensive to maintain.

This same monitor is also interlocked to automatically divert the effluent to the lagoon on sensing set concentrations of H_2S. The response is such that no sour effluent goes to the lake.

Before these changes to lagoon operation were approved, tests were conducted, in conjunction with the Ministry of the Environment, to prove the systems would work as planned.

CONCLUSIONS

To summarize one could ask the question, "What factors were most significant in making the improvements which have been described?" These factors are:

1.0 Environmental protection performance had a priority second only to safety.

2.0 Objectives were clear.

3.0 A technical group, dedicated to environmental protection, was formed to solve the problems.

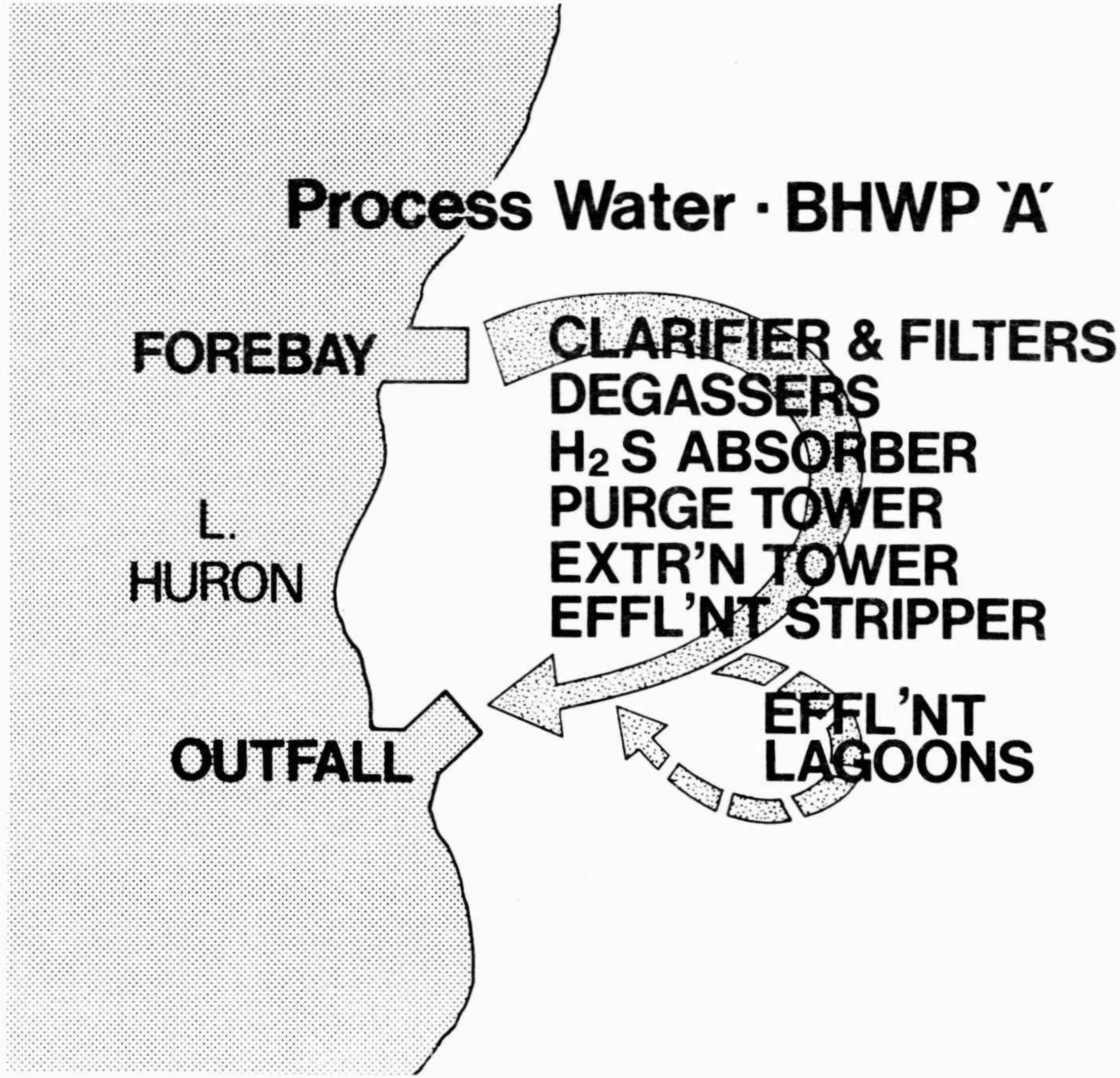
4.0 Effective communications were established and maintained with the Ministry of the Environment and reason prevailed.

5.0 Operator training was (and continues to be) an essential aspect of good performance.

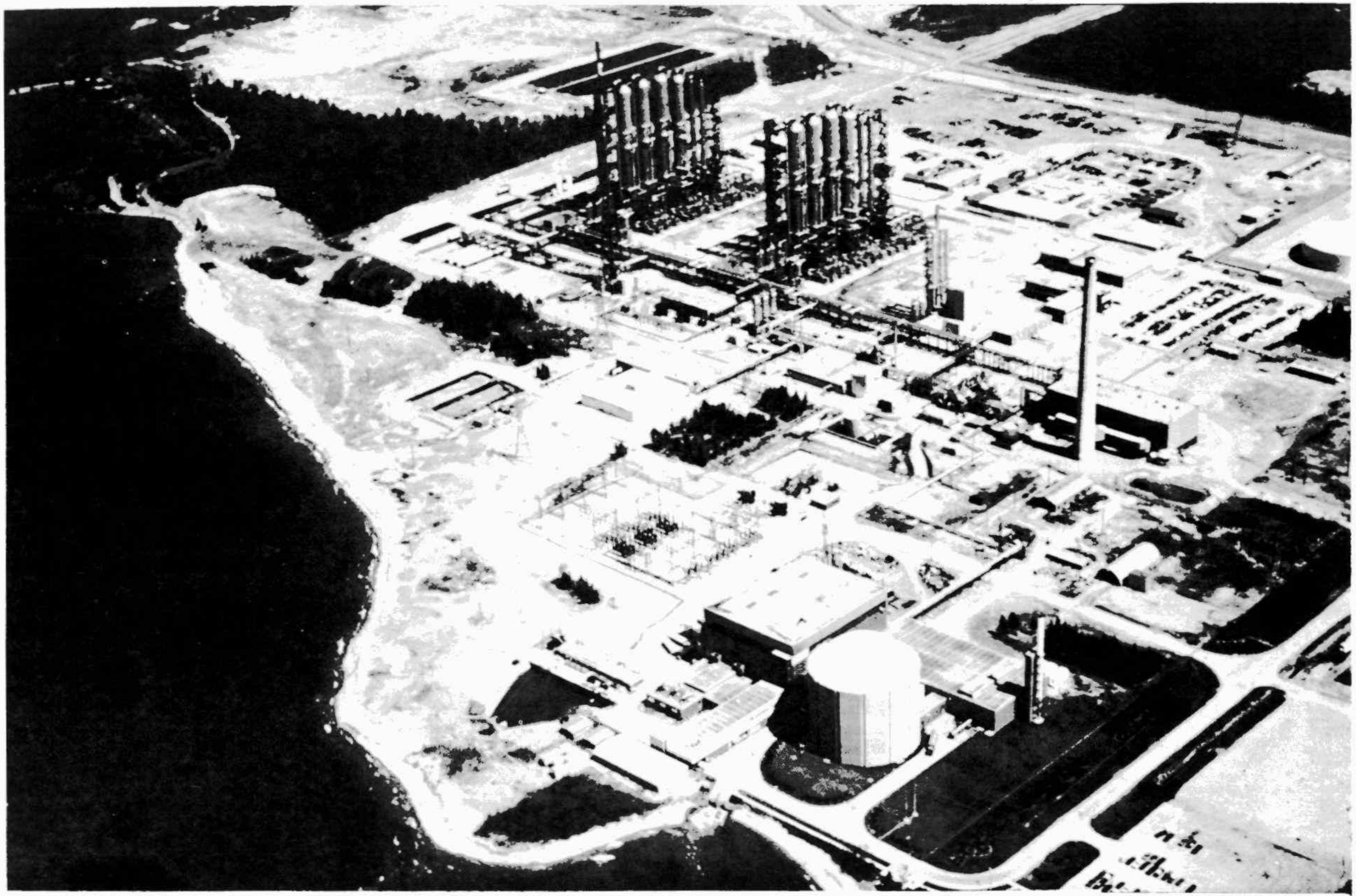
6.0 Day-to-day monitoring, followed by taking corrective actions, was essential.

7.0 Technical innovation has been effective in making improvements at minimum cost, e.g.: the new monitor and its interlocks to the lagoons.

The staff of Ontario Hydro are proud of their success in reducing emissions of H_2S to both air and water.

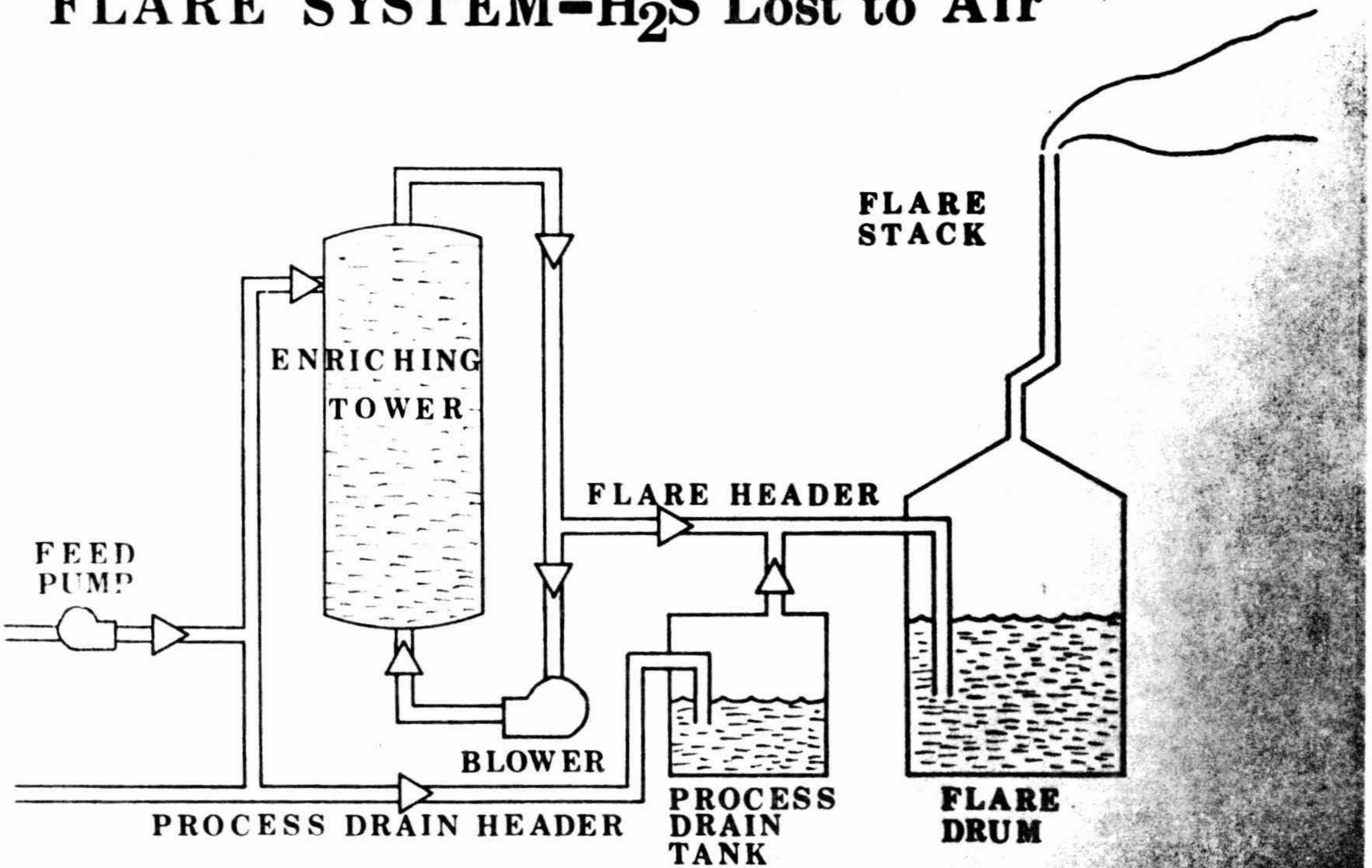

Process Water · BHWP 'A'
FOREBAY
L.
HURON
OUTFALL
CLARIFIER & FILTERS
DEGASSERS
H2 S ABSORBER
PURGE TOWER
EXTR'N TOWER
EFFL'NT STRIPPER
EFFL'NT
LAGOONS

Slide 1



Slide 2

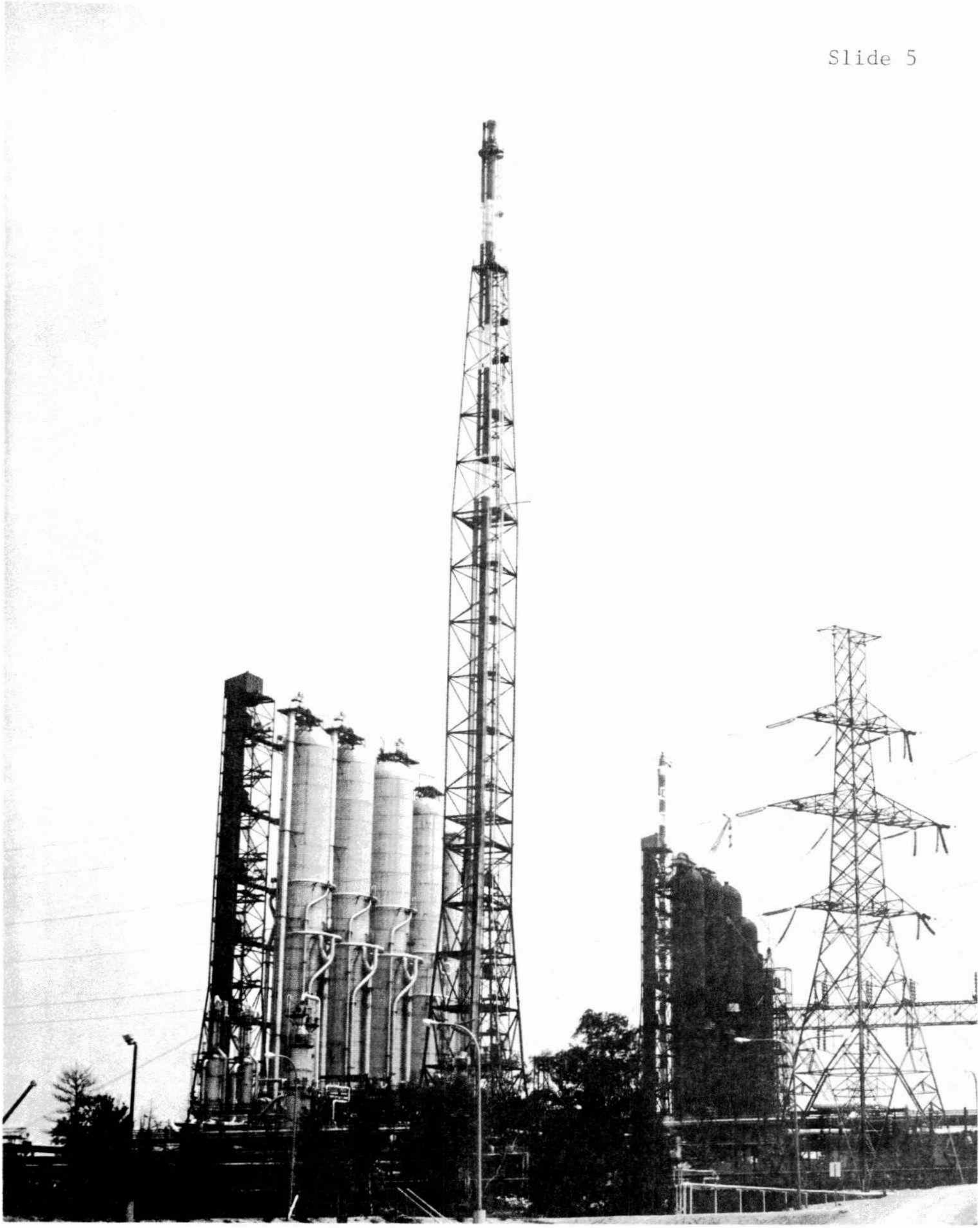
FLARE SYSTEM–H_2S Lost to Air

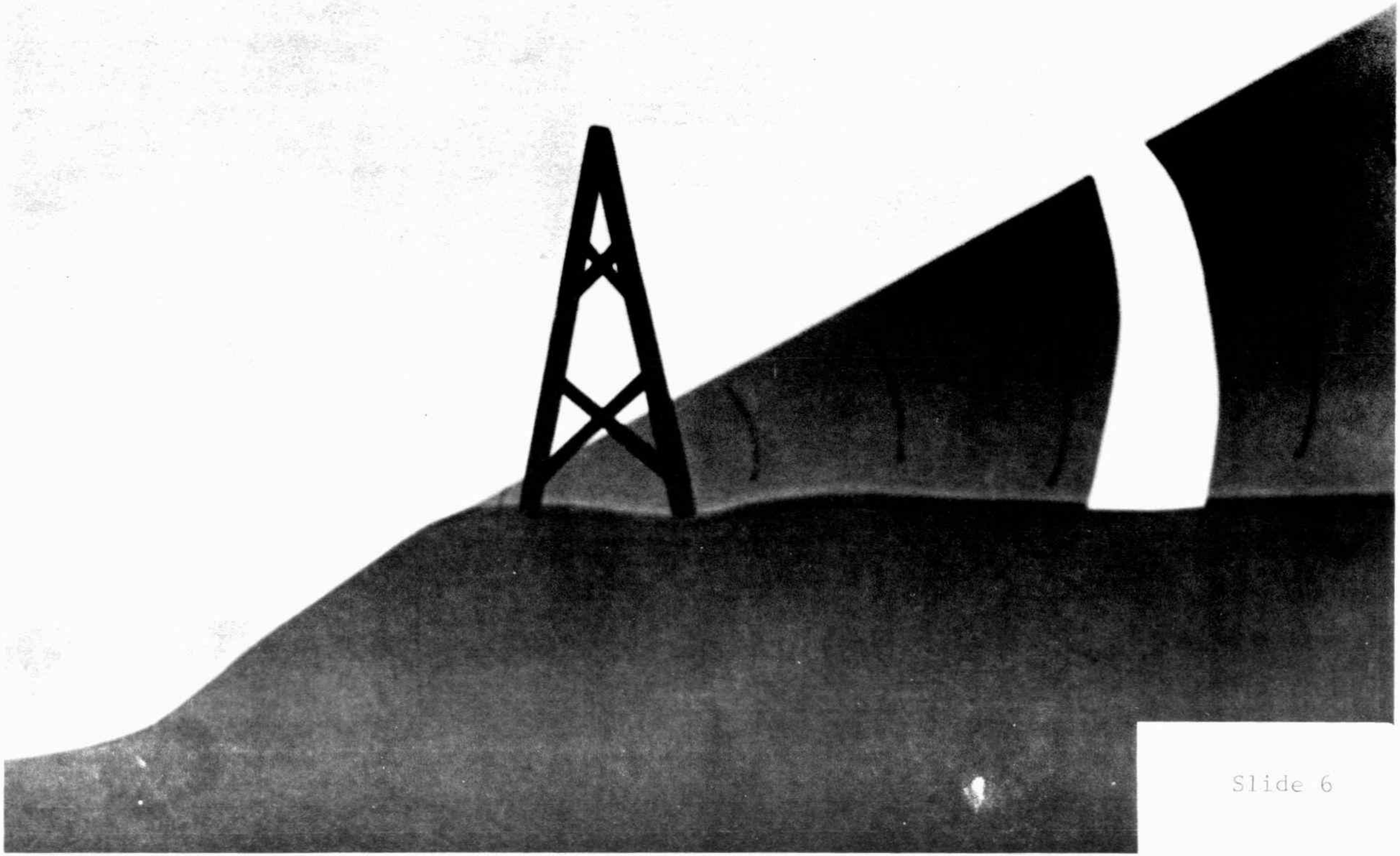


Slide 3

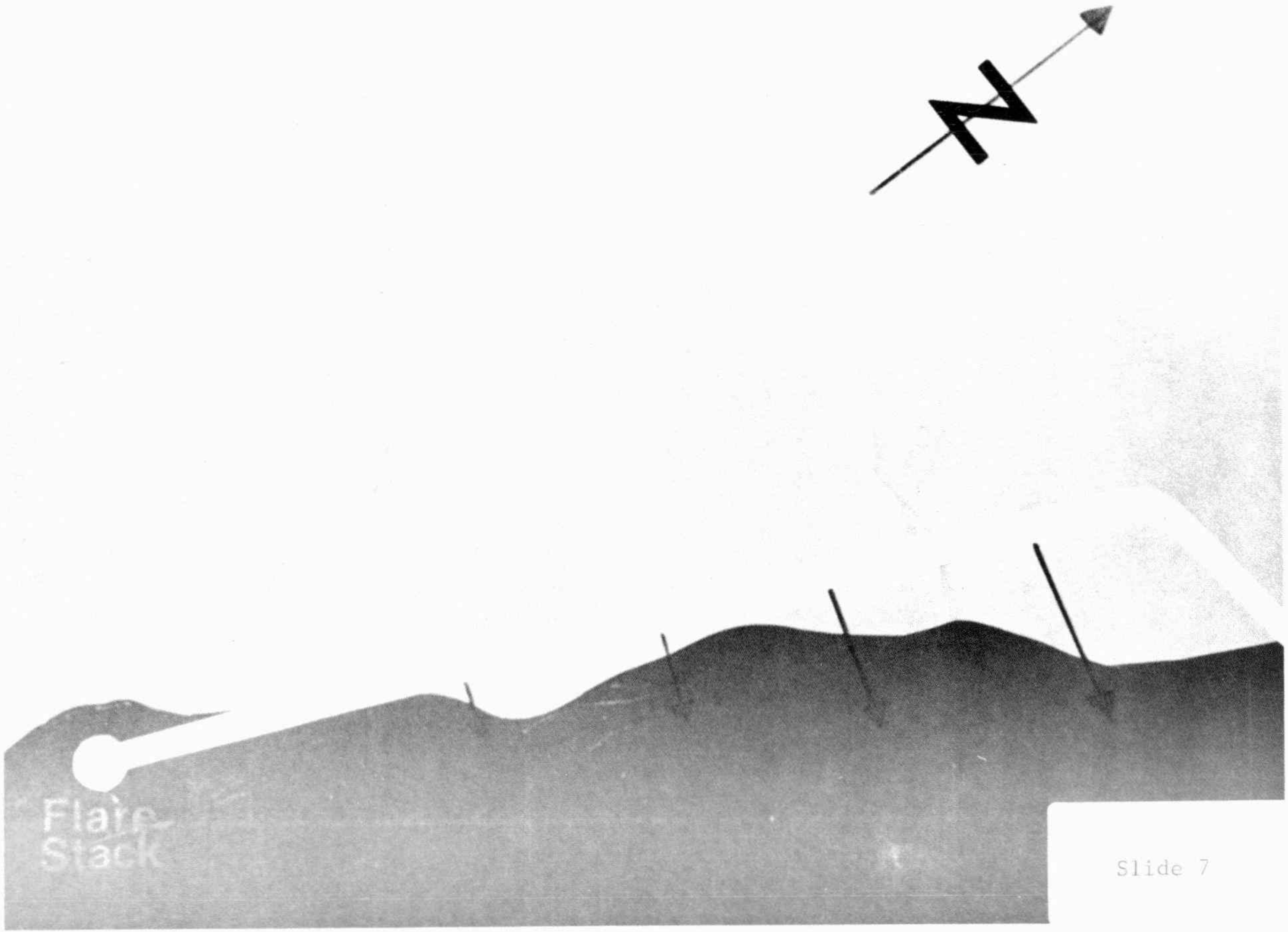
$$2\,H_2S + 3\,O_2 \rightarrow 2\,H_2O + 2\,SO_2$$

Slide 4



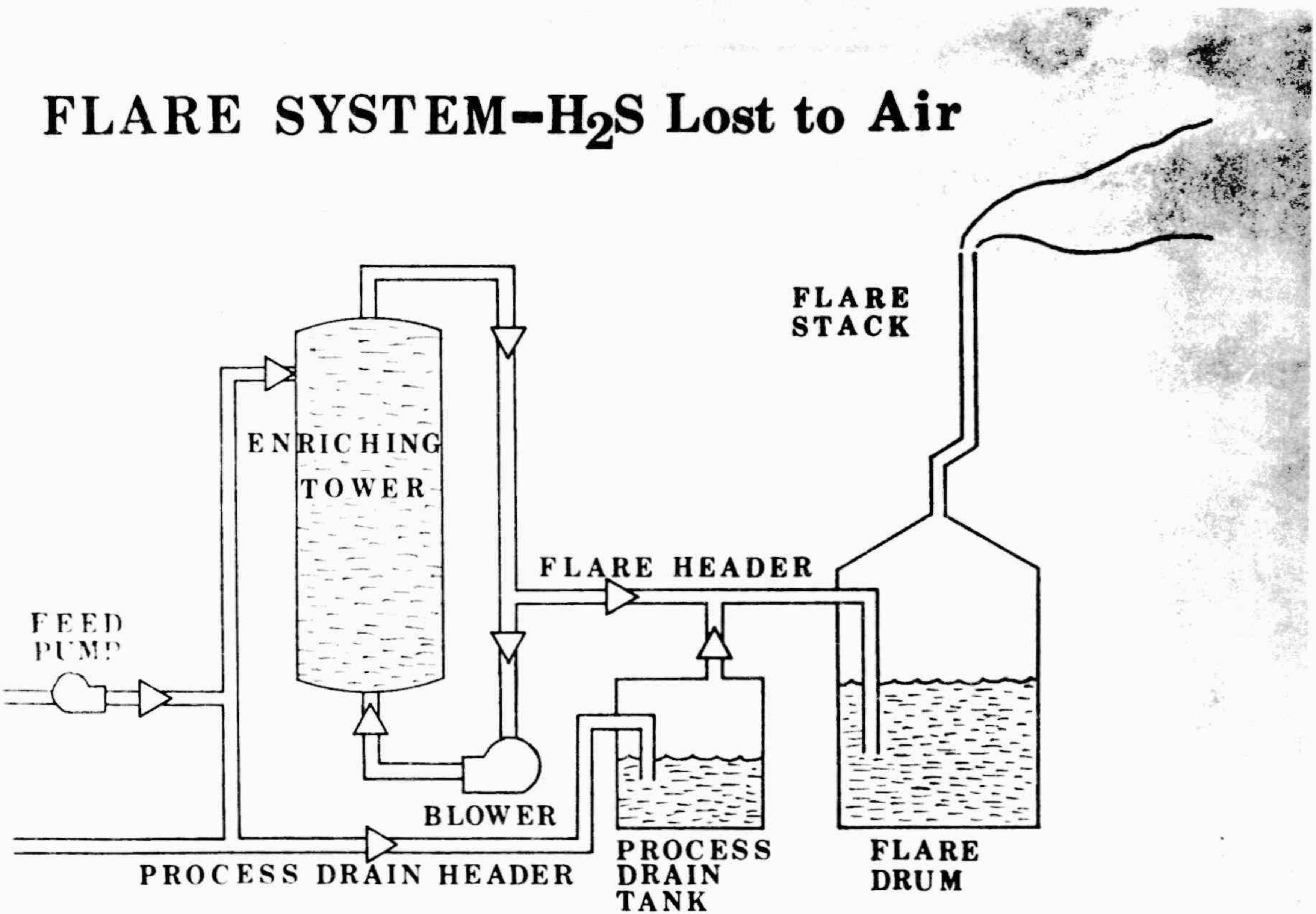


Slide 6

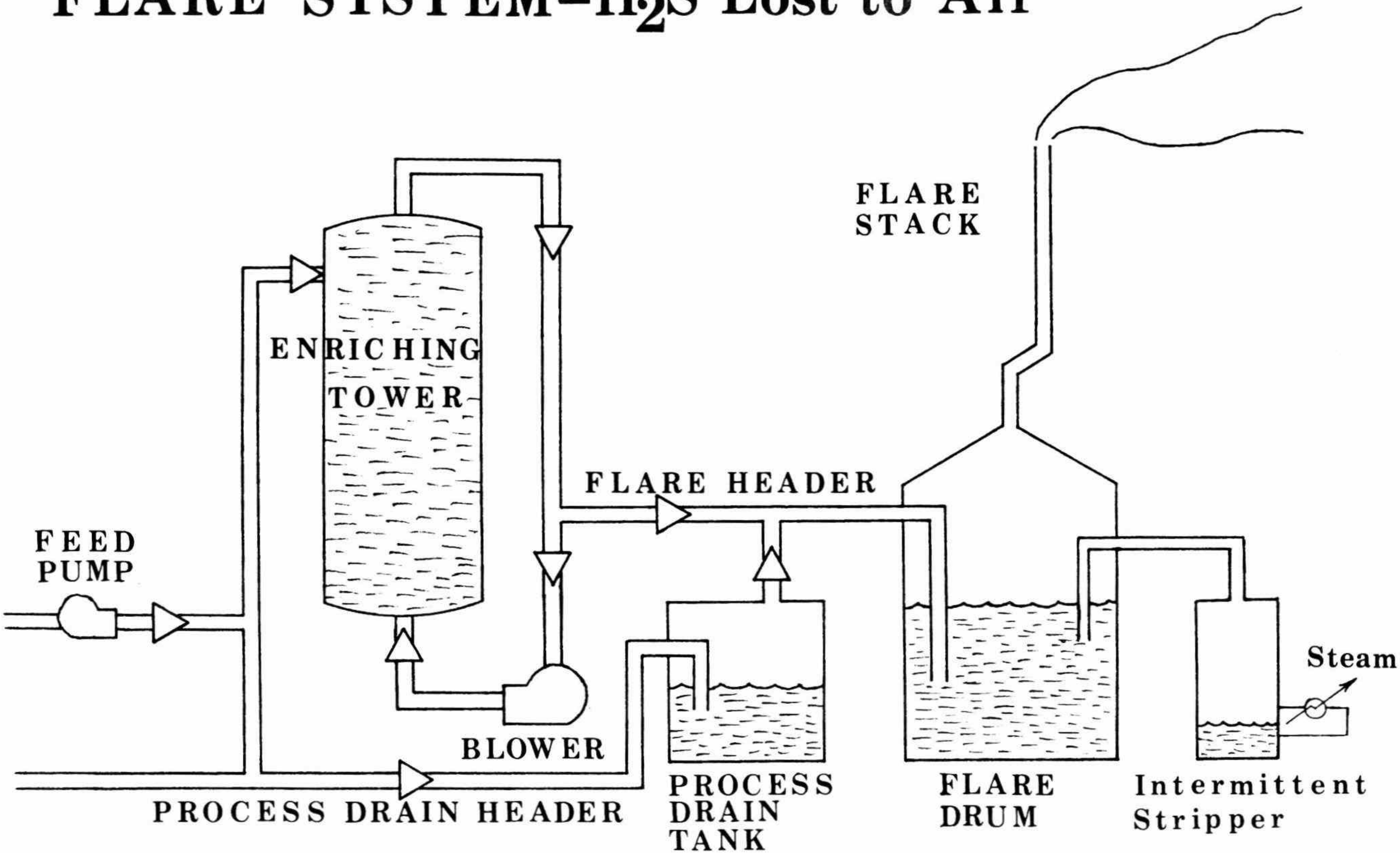


Slide 7

FLARE SYSTEM–H_2S Lost to Air

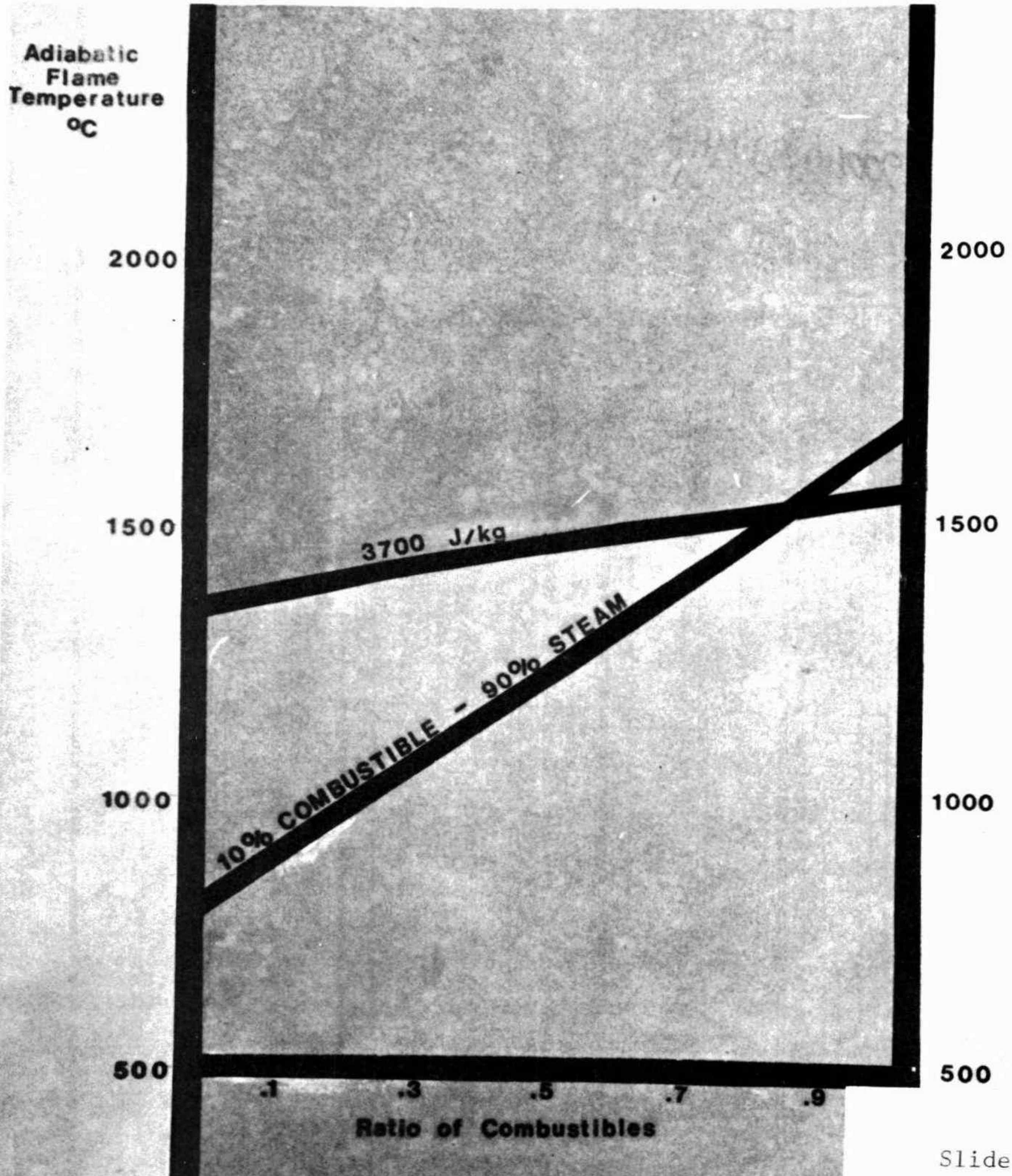


FLARE SYSTEM–H_2S Lost to Air



Slide 9

Theoretical Flame Temperatures



Slide 10

ENVIRONMENT PRIORITIES

1. Reduce H_2S emissions to the Flare Stack.

Slide 11

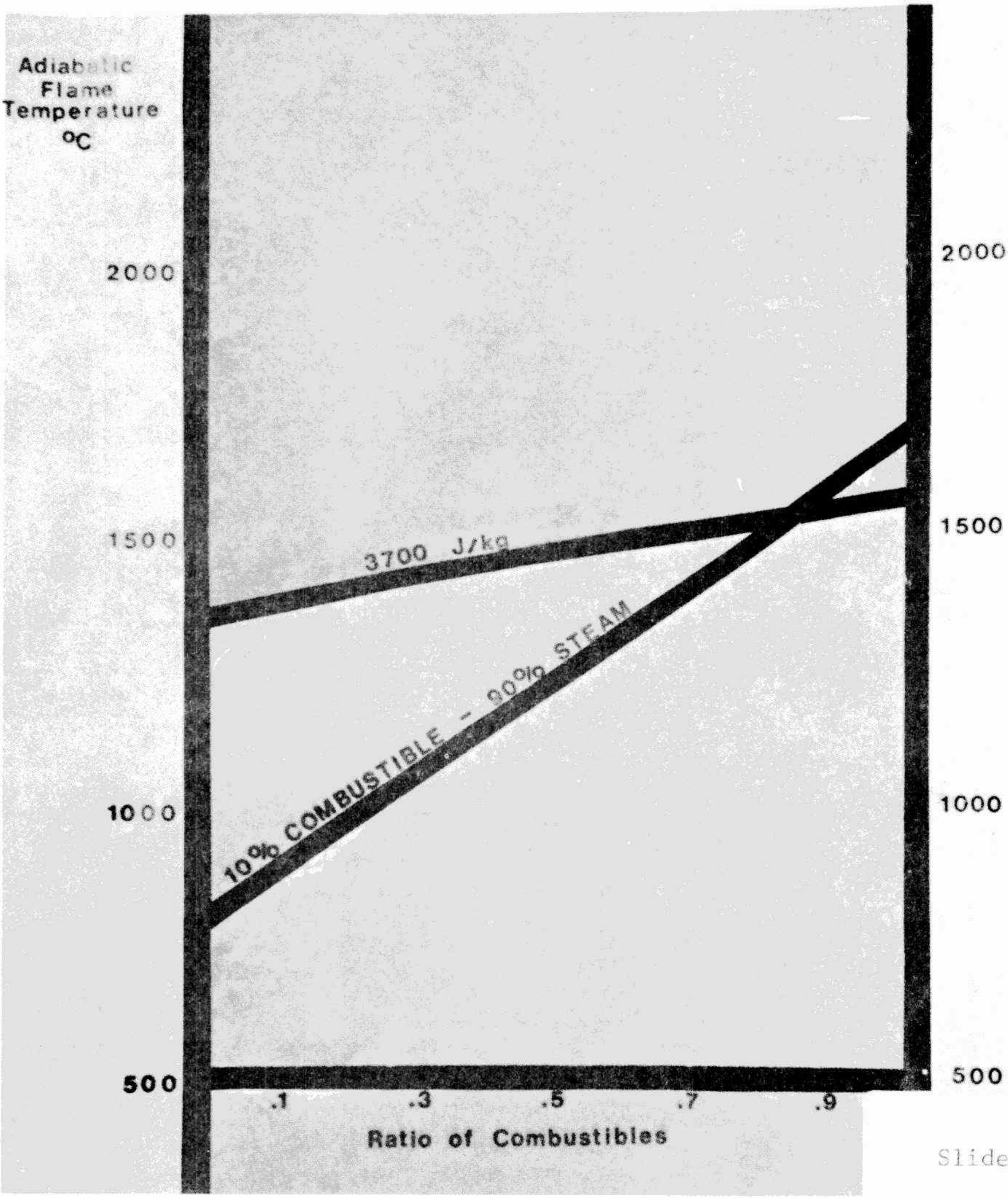
ENVIRONMENT PRIORITIES

1. Reduce H_2S emissions to the Flare Stack.

2. Increase BTU content of the Stack gas.

Slide 12

Theoretical Flame Temperatures



Slide 13

A. MANAGEMENT PRIORITIES

Safety

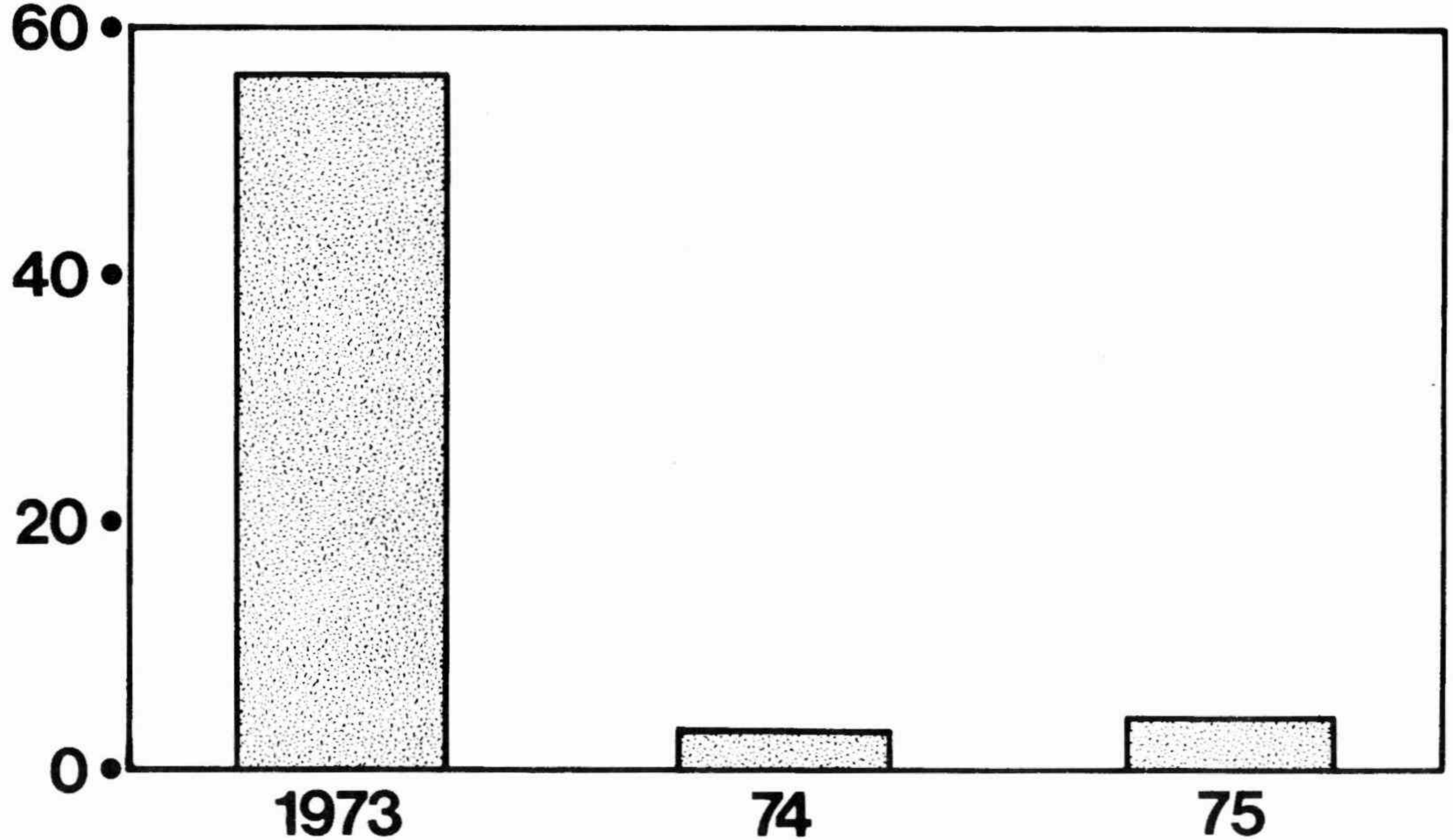
Environment

Production

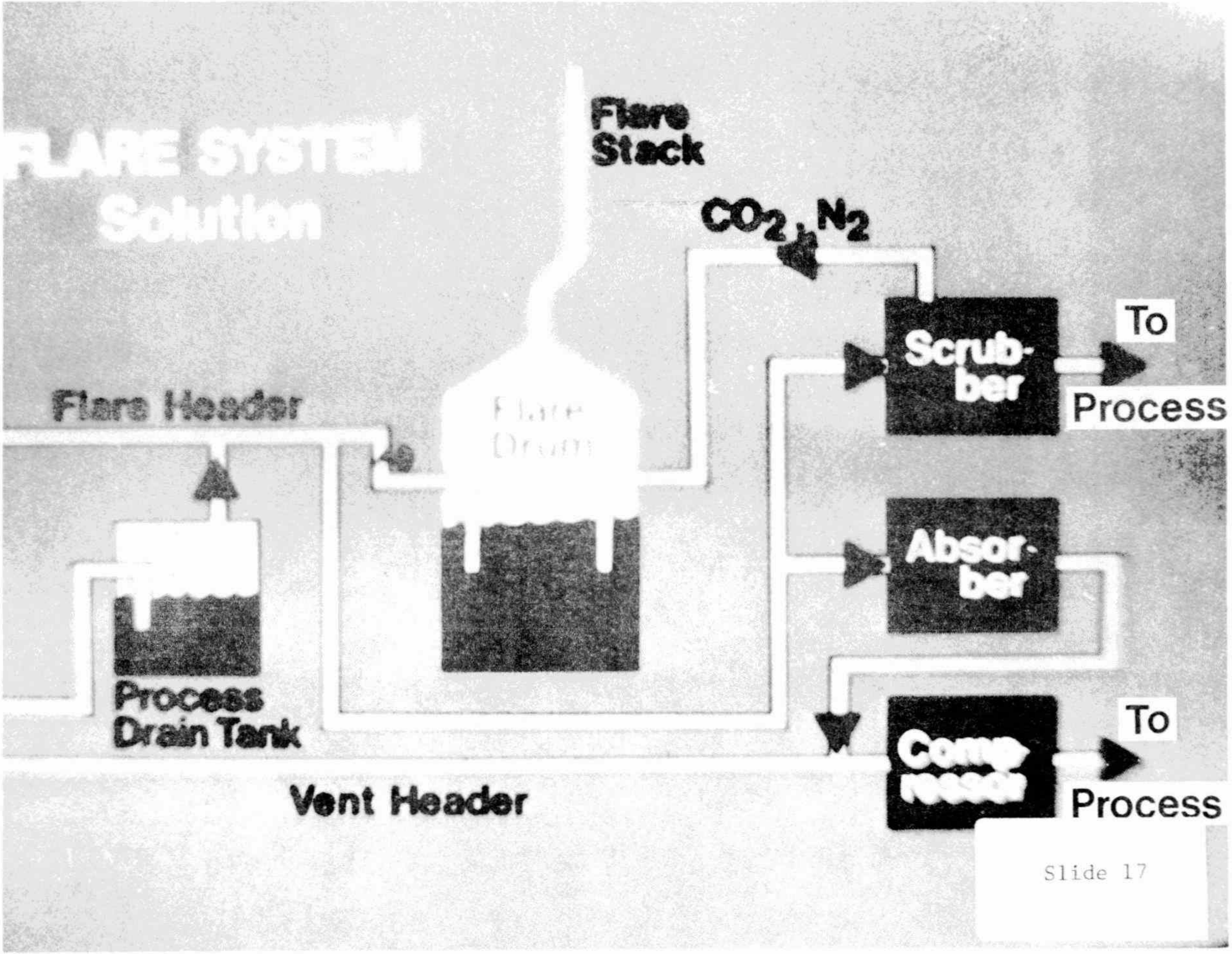
TRAINING

Operators
Engineers

ODOUR REPORTS FREQ'CY - BNPD



Slide 16


FLARE SYSTEM
Solution
Flare
Stack
CO_2, N_2
Scrub-
ber
To
Process
Flare Header
Flare
Drum
Absor-
ber
Process
Drain Tank
Comp-
ressor
To
Process
Vent Header

Slide 17

ENVIRONMENT PRIORITIES

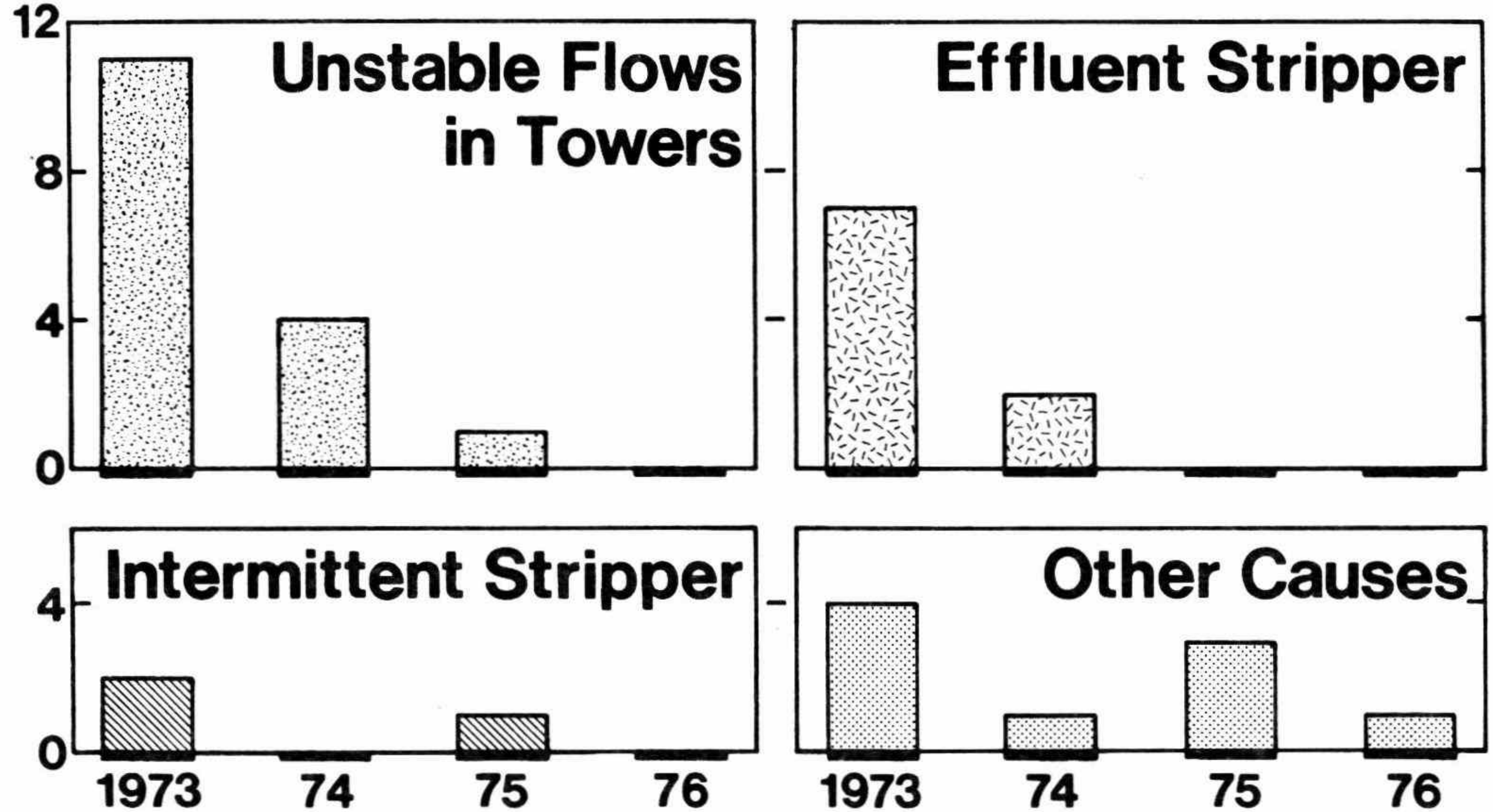
1. Reduce emissions of H_2S.
2. Ensure stack gas will burn.
3. Recirculate waste H_2S.

MANAGEMENT PRIORITIES

1. Environment priority is second only to safety.
2. Operator training.

Slide 18

H_2S Emissions to Water



Slide 19

WHEPP

a Mg't Tool Indicating

- Envir'al Perf'ce Trends

Slide 20 (a)

- Success in Meeting Prov. L'ts

WHEPP

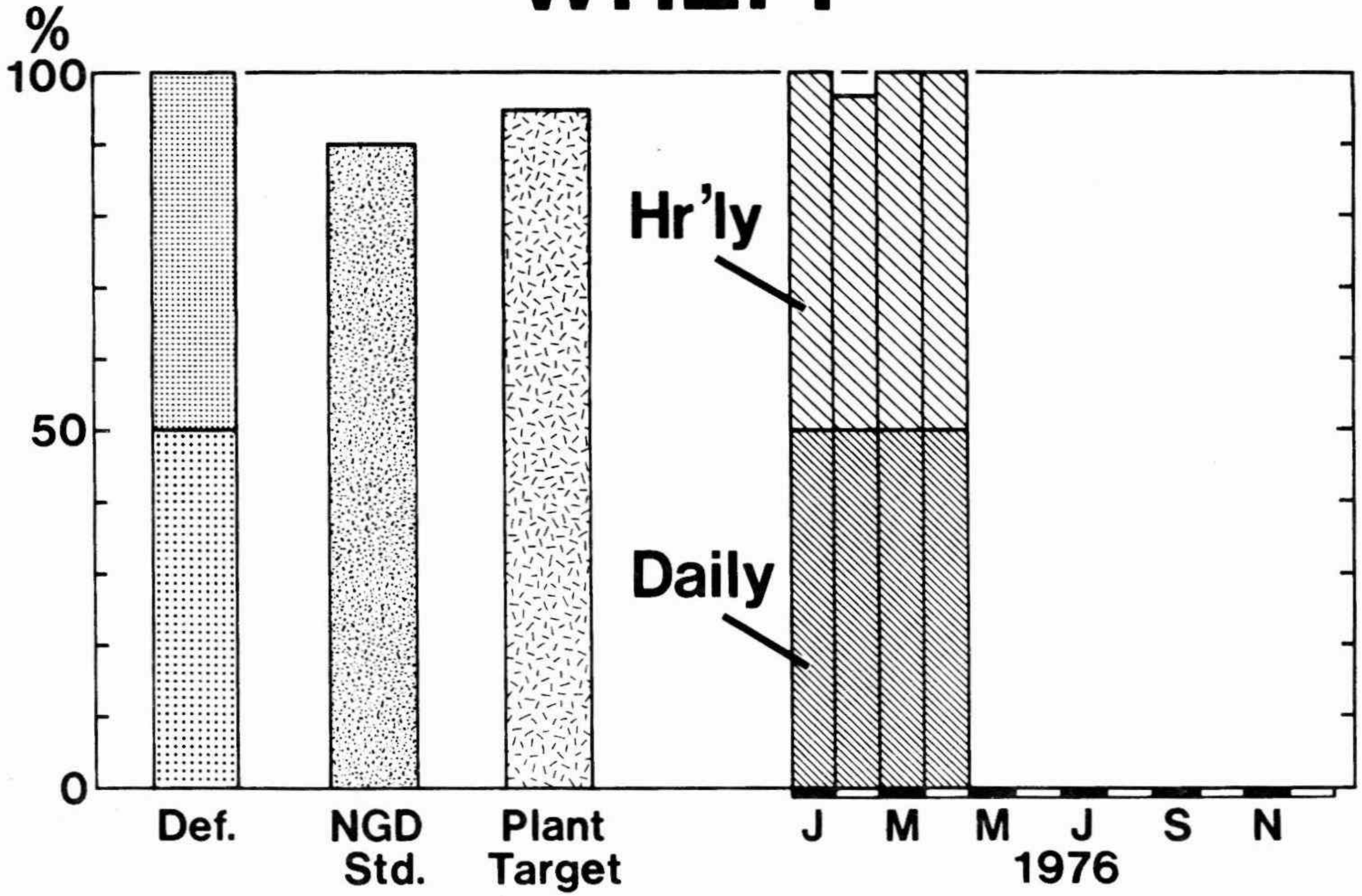
Av'ge Conc' of H_2S
in Joint Effluent:

Slide 20 (b)

- hr'ly 0.105 mg/kg

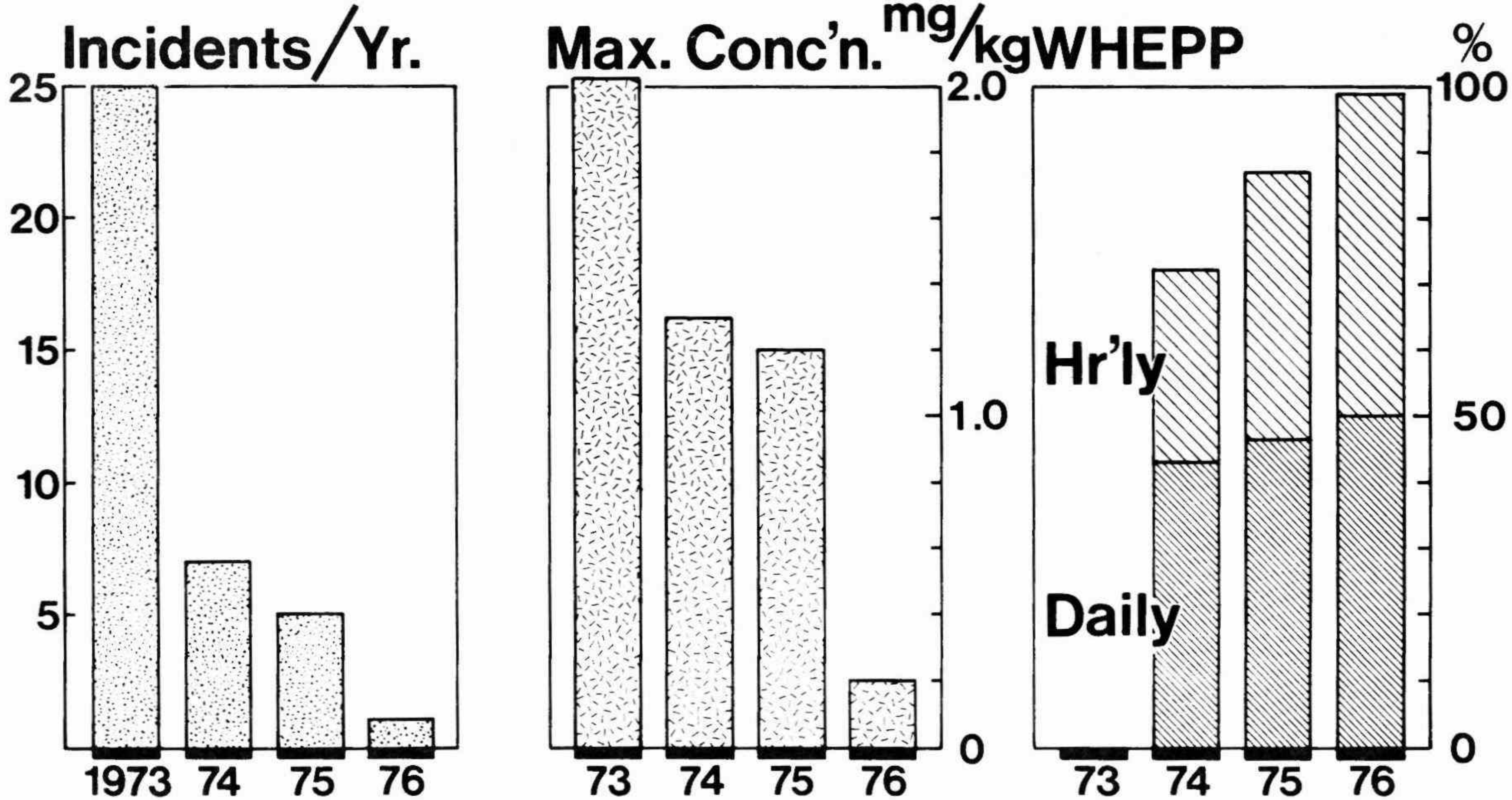
- daily 0.082 mg/kg

Envir'l Protection Perf'ce - BHWP A WHEPP

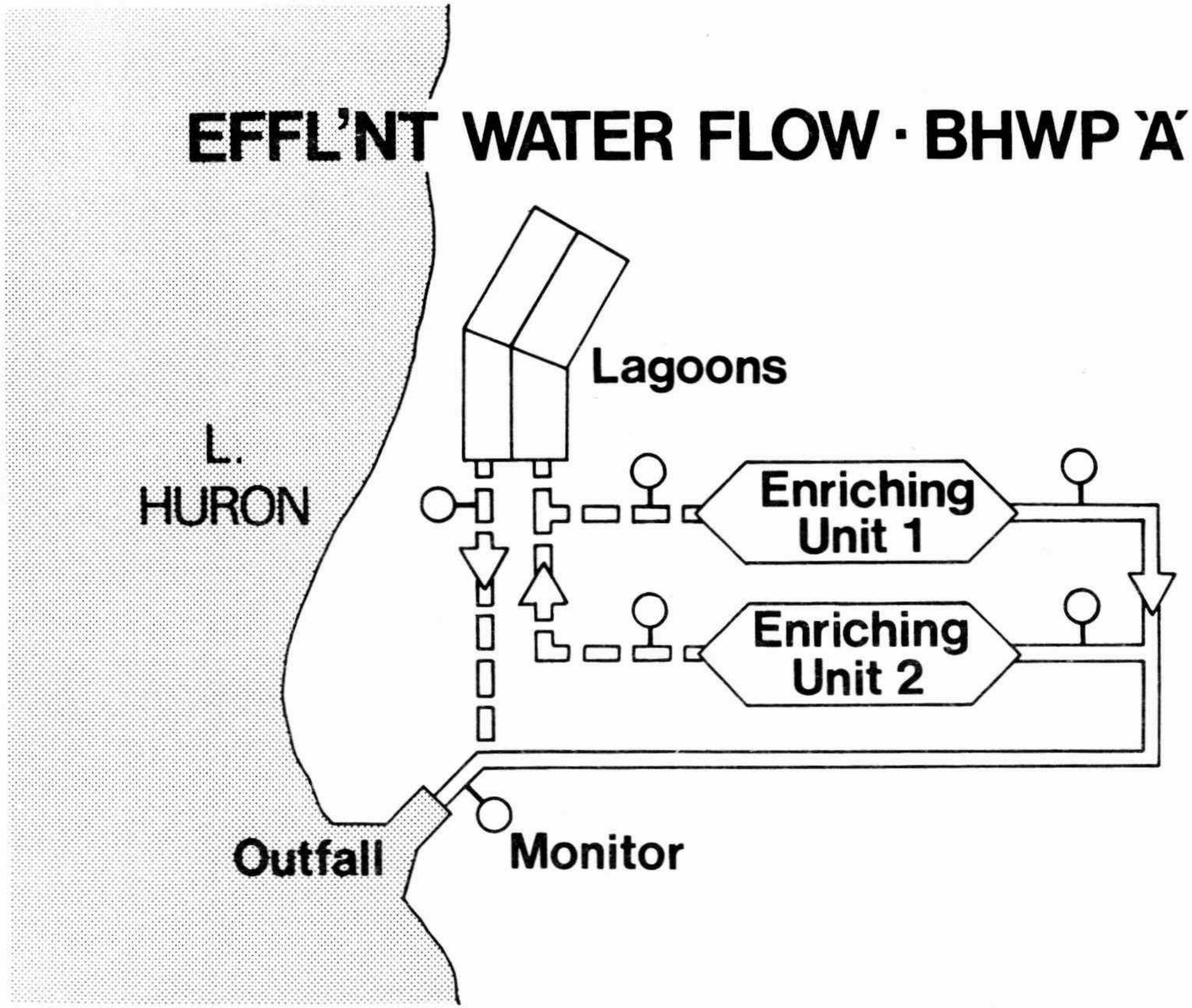


Slide 20 (c)

H_2S Emissions to Water - BHWP A

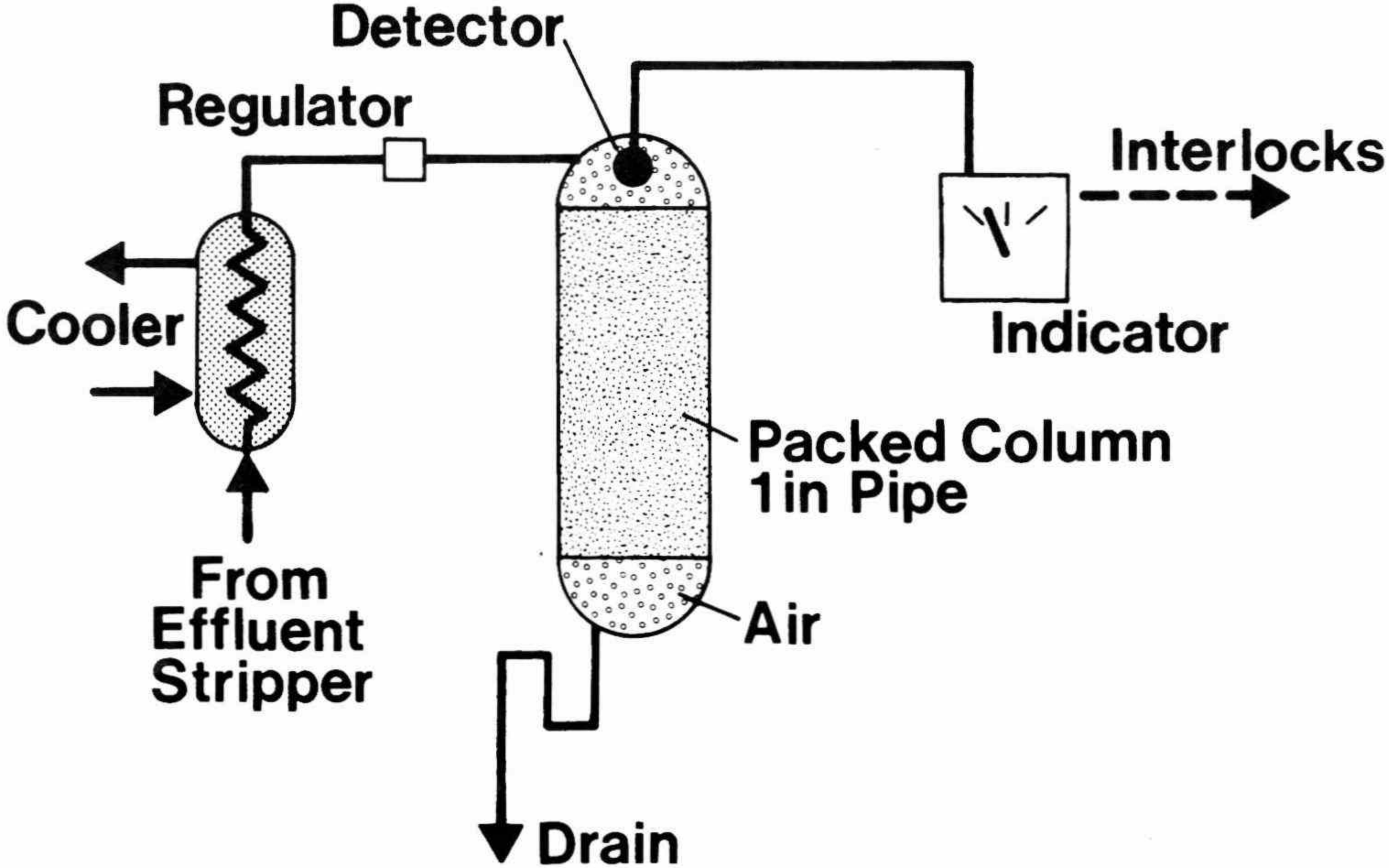


Slide 21


EFFL'NT WATER FLOW · BHWP 'A'
Lagoons
L.
HURON
Enriching
Unit 1
Enriching
Unit 2
Outfall
Monitor

Slide 22

H_2S MONITOR IN WATER · BHWP 'A'



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MINIMIZING THE COST OF AIR POLLUTION CONTROL IN ENAMEL CURING OVENS - A CASE STUDY

Early attempts, beginning in the mid 1950's, to eliminate the cause of odour complaints from tinplate sheet enamel curing ovens are briefly described. Advances in coating technology and increasing activity in the operation resulted in the generation of increasing quantities of offensive odours. As a result, during 1972 and 1973, five high temperature afterburners were installed on eight sheet curing lines which greatly increased the potential fuel requirements. To alleviate this additional fuel burden, heat recovery systems were installed to utilize the hot afterburner exhaust gases as the heat source for the oven heating zones. Fuel cost savings were expected to exceed the capital cost of the ductwork and controls within three years. Under some operating conditions, the operating fuel requirement of the combined oven/afterburner/heat recovery system can be less than the original requirement of the oven alone.

by

RALPH L. WHITTALL

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MINIMIZING THE COST OF AIR POLLUTION CONTROL IN ENAMEL CURING OVENS - A CASE STUDY

by

Ralph L. Whittall

CONTINENTAL HAS OPERATED A METAL CAN MANUFACTURING PLANT IN ETOBICOKE SINCE 1935. BY THE LATE 1940's BOTH THE OPERATION AND THE ADJACENT RESIDENTIAL AREA HAD GROWN SUBSTANTIALLY AND COMPLAINTS WERE BEGINNING TO BE RECEIVED OF ODOURS FROM THE TINPLATE DECORATING OPERATIONS OF THE PLANT. ALMOST ALL SO-CALLED TIN CANS HAVE INSIDE PROTECTIVE COATINGS OF ENAMELS AND SOME HAVE EXTERIOR VARNISH PROTECTION. THESE COATINGS HAVE BECOME MORE SOPHISTICATED OVER THE YEARS IN RESPONSE TO DESIRES TO INCREASE PRODUCT SHELF LIFE WHILE REDUCING COSTS BY REDUCTION IN TIN COATING THICKNESS AND FASTER CAN PRODUCTION SPEEDS. MANY OF THE SOLVENTS USED IN THE COATINGS HAVE UNPLEASANT ODOURS AND SOME BECOME OFFENSIVE WHEN SUBJECTED TO THE CURING TEMPERATURES OF 150° TO 220° C.

IN 1956 WE INSTALLED A NEW COATING LINE AND WITH IT A NATURAL GAS FIRED CATALYTIC AFTER BURNER. THE CATALYST CONSISTED OF PLATINUM COATED CERAMIC RODS, A MULTITUDE OF WHICH WERE PLACED IN THE OVEN EXHAUST STREAM IN A CROSS SECTION OF SUFFICIENT SIZE TO PROVIDE LOW EFFLUENT VELOCITY. THIS RAISED THE OVEN MAIN EXHAUST TEMPERATURE FROM ABOUT 125° C. TO 480° C. AND EFFECTIVELY DESTROYED THE ODIFEROUS ALDEHYDES AND KETONES IN THE EXHAUST GASES. UNHAPPILY, CATALYST LIFE WAS SHORT, MAINTENANCE COST WAS HIGH AND OPERATING COST, EVEN IN THOSE DAYS, WAS HIGH.

AT THAT PERIOD OF TIME THE METROPOLITAN AIR POLLUTION DEPARTMENT WAS ADVOCATING DISPERSAL IN THE ATMOSPHERE AS A MEANS OF POLLUTION CONTROL, AND,

AFTER CONSULTATION WITH THAT GROUP IN THE EARLY 1960's, WE REPLACED THE CATALYTIC UNIT WITH A HIGH STACK AND ADDED HIGH STACKS TO ALL THE OTHER COATER OVENS IN THE PLANT. THE EMISSION POINTS WERE THEREBY RAISED FROM ABOUT 10 METRES TO ABOUT 35 METRES ABOVE THE ROOF. WHILE THIS REDUCED THE NUISANCE IN THE IMMEDIATE NEIGHBOURHOOD, COMPLAINTS CONTINUED FROM FARTHER AFIELD AND UNDER CERTAIN ATMOSPHERIC CONDITIONS.

MEANWHILE, OUR U.S. PARENT COMPANY HAD BEEN WORKING CLOSELY WITH THE LOS ANGELES AIR POLLUTION AUTHORITIES AND EQUIPMENT SUPPLIERS TO PERFECT A SYSTEM FOR ENAMEL SHEET OVENS WHICH WOULD VIRTUALLY ELIMINATE HYDROCARBON EMISSION UNDER THE VARIOUS OPERATING CONDITIONS WE ENCOUNTER. BOTH HIGH TEMPERATURE (760° C.) AND CATALYTIC INCINERATION WERE BEING PURSUED. AFTER MUCH EFFORT, PRINCIPALLY IN BURNER DESIGN AND ITS PLACEMENT IN RELATION TO THE OVEN EFFLUENT STREAM, AN EFFICIENT HIGH TEMPERATURE UNIT BECAME A REALITY. IT WAS DECIDED IN 1970 TO INSTALL SUCH UNITS ON ALL THE OVEN LINES IN OUR PLANT. IN PART, THAT DECISION WAS A RECOGNITION THAT EVENTUALLY THE EMISSION OF HYDROCARBONS WOULD HAVE TO BE ELIMINATED, ALTHOUGH NOT YET REQUIRED BY REGULATIONS, AND THAT ELIMINATION OF ODOUR ALONE DID NOT MAKE MUCH ECONOMIC SENSE FOR THE LONG TERM.

WE WERE, OF COURSE, CONCERNED ABOUT THE ADDITIONAL COST OF FUEL TO OPERATE HIGH TEMPERATURE AFTERBURNERS, A CONCERN RECOGNIZED BY THE MINISTRY OF THE ENVIRONMENT WITH WHOM WE HAD BEEN IN CONSULTATION OVER THE YEARS. CONSIDERATION WAS GIVEN TO SEVERAL POSSIBLE MEANS OF UTILIZING THE WASTE HEAT, INCLUDING SPACE HEATING, GENERATION OF ELECTRICITY TO SERVE THE PLANT, AND AS A SOURCE OF HEAT FOR THE OVENS THEMSELVES. THE LAST WAS SELECTED

AS PROVIDING THE BEST ECONOMIC RETURN; IN SPITE OF THE FACT THAT THE OLDER EQUIPMENT WAS NOT SUITED TO HEAT RECOVERY BECAUSE ITS MULTI-ZONES MADE DISTRIBUTION AND CONTROL OF SUCH A HEAT SOURCE DIFFICULT AND EXPENSIVE.

A SYSTEM WAS DESIGNED CONSISTING OF FIVE IDENTICAL AFTERBURNER UNITS, INSTALLED ABOVE THE ROOF, TO SERVE THE EIGHT OVEN LINES OPERATED IN THE PLANT. THUS, THREE PAIRS OF OVENS WOULD BE SERVED BY ONE UNIT FOR EACH PAIR AND THE OTHER TWO OVENS WOULD EACH HAVE ITS OWN AFTERBURNER. THAT ARRANGEMENT WAS POSSIBLE BECAUSE OF SUITABLY APPROPRIATE OVEN EXHAUST RATES AND THE FACT THAT EACH PAIR WOULD NORMALLY OPERATE AT THE SAME TIME. IT ALLOWED WELCOME ECONOMICS IN DESIGN AND FABRICATION OF THE AFTERBURNERS AND WASN'T EXPECTED TO INCREASE OPERATING COSTS.

IN 1972 TWO AFTERBURNER UNITS WERE INSTALLED, ONE OF WHICH WAS EQUIPPED WITH THE NECESSARY DUCTWORK AND CONTROLS TO PROVIDE ALL OF THE HEAT REQUIRED BY THE OVEN IT SERVED. FIGURE 1 DEPICTS A CROSS SECTION OF THE AFTERBURNER. OVEN EXHAUST AT TEMPERATURE T_1 ENTERS THE AFTERBURNER THROUGH THE TWO-PASS HEAT EXCHANGER WHERE THE TEMPERATURE RISES TO T_2. THE BURNER FURTHER RAISES THE TEMPERATURE TO 760° C., AFTER WHICH THE "CLEAN" EMISSION GASES PASS THROUGH THE HEAT EXCHANGER AND EXIT FROM THE SYSTEM AT APPROXIMATELY 480° C. THE GASES ARE EITHER RECYCLED TO THE PROCESS OVEN OR EXHAUSTED INTO THE ATMOSPHERE.

FIGURE 2 IS A SCHEMATIC REPRESENTATION OF THE HEAT RECOVERY SYSTEM. HIGH TEMPERATURE EXHAUST AIR FROM THE AFTERBURNER IS DISTRIBUTED THROUGH THE

HEAT TRUNK TO THE SIX OVEN HEATING ZONES AND THE WICKET PREHEAT (WPH) SECTION. THE HOT "WASTE" AIR SERVES AS THE HEAT SOURCE FOR THE OVEN HEATING ZONES WITH TEMPERATURES CONTROLLED BY THE EXISTING ZONE CONTROLLERS, WHICH IN TURN OPERATE THE PNEUMATIC DAMPERS LOCATED IN THE HOT AIR FEEDER DUCTS. THE EXISTING ZONE BURNERS ARE LEFT IN PLACE AND MAY BE UTILIZED IN LIEU OF THE HEAT RECOVERY SYSTEM. CHANGEOVER FROM HEAT RECOVERY TO BURNERS, AND VICE VERSA, IS EASILY ACCOMPLISHED BY MEANS OF A MODE SWITCH MOUNTED ON THE INSTRUMENT PANEL.

AUXILIARY SUBSYSTEMS UTILIZED IN THE INSTALLATION INCLUDE:

1. A DRAFT-PRESSURE CONTROL STATION TO MAINTAIN ADEQUATE STATIC PRESSURE IN THE TRUNK DUCT AND, THUS INSURE SUFFICIENT AIR SUPPLY TO ALL ZONES;

2. A WPH SECTION EXHAUST SYSTEM DESIGNED TO EVACUATE AN AMOUNT OF AIR EQUIVALENT TO THAT SUPPLIED FROM THE HEAT TRUNK;

3. AN EXTENSIVE OVEN-INCINERATOR-SHEET FEED INTERLOCK SYSTEM WHICH AFFORDS PROCESS AND EQUIPMENT PROTECTION. THE INTERLOCK SYSTEM PREVENTS FEEDING SHEETS WHEN THE INCINERATOR IS NOT WITHIN THE ACCEPTABLE OPERATING TEMPERATURE RANGE, AND THUS ASSURES EFFECTIVE POLLUTION CONTROL WHILE PREVENTING UNDERBAKED SHEETS.

START-UP AND CHECK-OUT OF THE AFTERBURNER AND HEAT RECOVERY SYSTEM WAS CONDUCTED IN AUGUST 1972. THIS WAS FOLLOWED BY OVEN QUALIFICATION TESTS (TIME VS TEMPERATURE BAKE CURVES). ALL RUNS WERE CONDUCTED WITH THE SAME COATING MATERIAL, SHEET SIZE AND SPEED, AND OVEN BAKE. READINGS

WERE TAKEN ON A FIVE POINT SPEEDOMAX RECORDER WITH 260^{o} C. CHART, THE FIVE MEASUREMENTS BEING AT STANDARD POINTS ON THE SURFACE OF A TEST SHEET.

TWO TESTS WERE RUN ON BURNER MODE, ADHERING TO THE ESTABLISHED TEMPERATURE SETTINGS REQUIRED FOR ACCEPTABLE BAKES IN THE OVEN. IMMEDIATELY THEREAFTER, TWO ADDITIONAL TESTS WERE RUN UNDER THE SAME PRODUCTION CONDITIONS, BUT USING THE HEAT RECOVERY MODE. ANALYSIS OF THESE TYPICAL CURVES CONFIRMED THAT THE PROCESS BAKE CONDITIONS WERE NOT AFFECTED BY THE ALTERNATE HEAT SOURCE. THUS, WE WERE SATISFIED THAT THE PRINCIPLE WORKED; IT REMAINED TO BE DETERMINED IF AND HOW OPERATING FUEL CONSUMPTION COULD BE MINIMIZED BY CHANGING OPERATING CONDITIONS OR SYSTEM DESIGN SO THAT CONSTRUCTION COULD PROCEED ON THE ADDITIONAL UNITS SCHEDULED FOR 1973, TWO OF WHICH WERE TO UTILIZE HEAT RECOVERY.

IN PREPARATION FOR THE ORIGINAL PROGRAM, A METER HAD BEEN INSTALLED ON THE NATURAL GAS TRUNK LINE TO THE OVEN SO THAT WE HAD CONSIDERABLE DATA ON GAS CONSUMPTION OVER VARIOUS OPERATING CONDITIONS OF OVEN BAKE TEMPERATURE AND SHEET WEIGHT AND SPEED. IN RETROSPECT, WE SHOULD HAVE ALSO DETERMINED GAS CONSUMPTION AT EACH OVEN ZONE. WE THOUGHT THAT WE KNEW THE PROPORTION OF THE TOTAL USED IN EACH ZONE, BUT SUBSEQUENTLY DISCOVERED THAT WAS NOT SO. ACCURATE KNOWLEDGE WOULD HAVE ENABLED US TO REDUCE AFTERBURNER CAPACITY AND DUCTWORK SIZES, AND HENCE THE CAPITAL COSTS.

OVER THE SIX MONTH PERIOD FROM AUGUST 1972 TO JANUARY 1973 WE MONITORED GAS CONSUMPTION OF THE AFTERBURNER WITH THE SYSTEM OPERATING ON HEAT RECOVERY MODE. AS EXPECTED, THE AFTERBURNER GAS CONSUMPTION RATE VARIED GREATLY

WITH OPERATING CONDITIONS, RANGING FROM 1400 to 2150 kJ/sec. THE PRINCIPAL REASON FOR THAT VARIATION IS THE CONTRIBUTION TO THE AFTERBURNER HEAT REQUIREMENT AFFORDED BY THE SOLVENTS IN THE OVEN EFFLUENT, WHICH OF COURSE VARY WITH CONSTITUENT, ENAMEL FILM WEIGHT AND THE TINPLATE SHEET SIZE. OVEN BAKE TEMPERATURE IS ALSO A FACTOR BECAUSE THE AFTERBURNER IS RAISING A VARIABLE INPUT TEMPERATURE TO A FIXED OUTPUT TEMPERATURE.

LOWER TEMPERATURE BAKES ARE ASSOCIATED WITH SPECIFIC COATING MATERIALS AND HENCE CERTAIN SOLVENTS. THE SAME IS TRUE FOR THE HIGHER TEMPERATURE BAKES. OUR OBJECTIVE WAS TO MAKE AN ECONOMIC ANALYSIS OF THE SYSTEM IN ORDER TO ESTABLISH RELATIVE FUEL VOLUME AND COST SAVINGS. THEREFORE, A TIME-WEIGHTED AVERAGE FUEL CONSUMPTION WAS DETERMINED ON THE BASIS THAT THE PROPORTION OF HIGH BAKES TO LOW BAKES IS APPROXIMATELY 3 TO 1. THE FOLLOWING ARE TIME WEIGHTED, AVERAGE, EQUIVALENT NATURAL GAS CONSUMPTIONS:

<u>OVEN WITH NO AFTERBURNER</u>

LOW BAKES	-	790 kJ/sec.
HIGH BAKES	-	1088 kJ/sec.
TIME-WEIGHTED AVERAGE ALL BAKES	-	1000 kJ/sec.

<u>AFTERBURNER ONLY</u>

TIME-WEIGHTED AVERAGE ALL COATINGS	-	1645 kJ/sec.

THE FOLLOWING ANALYSIS ESTABLISHES THE INCREASED FUEL REQUIREMENTS WHEN AN AFTERBURNER IS ADDED TO A SHEET COATING OVEN. THE ANALYSIS IS INTENDED TO SHOW HOW FUEL CONSERVATION RESULTS WHEN HEAT RECOVERY IS USED TO INTEGRATE THE TWO PROCESSES. ALL SUBSEQUENT CALCULATIONS ARE BASED ON 6000 OPERATING HOURS PER YEAR. USING THE TIME-WEIGHTED AVERAGES, THE ANNUAL FUEL CONSUMPTION FOR THE OVEN IS:

$$(1000 \text{ kJ/sec.}) \times (6000 \times 60 \times 60 \text{ secs/yr.}) = 2.16 \times 10^{10} \text{ kJ/yr}$$

AND FOR THE AFTERBURNER IS:

$$(1645 \text{ kJ/sec.}) \times (6000 \times 60 \times 60 \text{ secs/yr.}) = 3.55 \times 10^{10} \text{ kJ/yr}$$

TOTAL OVEN AND AFTERBURNER FUEL REQUIREMENTS ARE:

$$(2.16 \times 10^{10} \text{ kJ/yr}) + (3.55 \times 10^{10} \text{ kJ/yr}) = 5.71 \times 10^{10} \text{ kJ/yr}$$

INTEGRATING THE TWO PROCESSES WITH A HEAT RECOVERY SYSTEM ELIMINATES THE OVEN FUEL REQUIREMENT AND ITS RELATED COST. FUEL CONSUMPTION IN THE COMBINED SYSTEM IS THAT SHOWN ABOVE FOR THE INCINERATOR ALONE, AND THOUGH GREATER THAN THE OVEN ALONE, IS CONSIDERABLY LOWER THAN AN INDEPENDENT OVEN-AFTERBURNER SYSTEM. WHERE AFTERBURNERS ARE REQUIRED, THE FUEL COST SAVINGS MAY, AND TO-DAY PROBABLY WOULD, JUSTIFY THE ADDITIONAL CAPITAL COST OF HEAT RECOVERY.

YOU WILL NOTE THAT THIS WORK WAS DONE IMMEDIATELY PRIOR TO THE PERIOD IN WHICH FUEL COST BEGAN TO ESCALATE RAPIDLY. TO SAY WE WERE WELL TIMED WOULD BE AN UNDERSTATEMENT. PRICING ACTION IN THE MIDDLE EAST ADDED

IMPETUS TO OUR DESIRE TO MAKE FURTHER REDUCTION IN FUEL CONSUMPTION.

THE FACTORS AFFECTING THE OPERATING FUEL COST OF AN AFTERBURNER ARE: 1) THE SOLVENT COMPOSITION OF THE COATINGS; 2) THE COST OF THE FUEL; 3) THE EXHAUST RATE AT WHICH THE OVEN IS OPERATED. TRADITIONALLY, OUR LARGE SHEET COATER OVENS HAD BEEN OPERATED AT AN EXHAUST RATE OF ABOUT 280 STANDARD m^3/min. IN ORDER TO ACCOMMODATE MAXIMUM DESIGN SPEED, COATING WEIGHT AND SHEET SIZE; AND ENSURE MAINTENANCE OF THE ATMOSPHERE WITHIN THE OVEN BELOW 25% OF THE LOWER EXPLOSIVE LIMIT, AN INSURANCE REQUIREMENT. PREVIOUS WORK WITH VARIABLE EXHAUST OVENS, IN WHICH THE EXHAUST RATE WAS AUTOMATICALLY VARIED TO MAINTAIN 25% LEL BY MONITORING THE AIR IN THE FIRST ZONE OF THE OVEN, HAD SHOWN US THAT 280 m^3/min. WAS NOT REQUIRED IN PRACTICE. ACCORDINGLY, WHEN THE AFTERBURNERS WERE INSTALLED, THEY WERE DESIGNED, AND THE COATER OVENS WERE RESET FOR, 226 STD. m^3/min. THAT EXHAUST RATE WAS CHOSEN MAINLY BECAUSE WE EXPECTED TO REQUIRE THAT AMOUNT OF AFTERBURNER EXHAUST (AT 480^{o} C) TO ENSURE SATISFACTORY OPERATION OF THE OVEN UNDER THE HEAT RECOVERY SYSTEM.

IT DIDN'T WORK OUT THAT WAY. FLOW RATES WERE DETERMINED IN THE DUCTS **FEEDING** THE OVEN HEATING SECTIONS UNDER VARIOUS OPERATING CONDITIONS AND FOUND TO BE LESS THAN HALF THOSE EXPECTED, SOMETIMES SUBSTANTIALLY LESS. EXHIBIT 3 IS A TYPICAL TEST RESULT WHICH SHOWED THAT A 170^{o} C - 8 MINUTE BAKE REQUIRED 91 STD m^3/min. OF AIR AT 402 - 438^{o} C TO MAINTAIN OPERATION AND ANOTHER 142 STD. m^3/min. WAS EXHAUSTED TO ATMOSPHERE.

AS A RESULT OF THIS EXPERIENCE IT WAS DECIDED TO MAKE A FURTHER MAJOR REDUCTION IN EXHAUST RATE. A MINIMUM RATE OF 141.5 STD. m^3/min. WAS

CALCULATED AS NECESSARY TO PREVENT SOLVENT CONCENTRATIONS FROM EXCEEDING 25% LEL. THE TESTS HAD SHOWN THAT 113 TO 141.5 STD. m^3/min. OF HIGH TEMPERATURE AIR WILL SUSTAIN ALL OVEN BAKES. ON THAT BASIS IT WAS DETERMINED PRACTICAL TO REDUCE THE OVEN EXHAUST RATE TO 170 STD. m^3/min., STILL ALLOWING SOME FACTOR OF SAFETY FOR UNUSUAL OPERATING CONDITIONS. IT WILL BE RECALLED THAT DESIGN CONDITIONS OF THESE OVENS INCLUDED AN EXHAUST RATE OF 280 STD m^3/min. WE WERE NOW TRYING TO REACH A RATE 40% LOWER AND WORKING WITH A RECTANGULAR BOX OVER 30 METRES IN LENGTH IN WHICH AIR FLOW AND TEMPERATURE MUST BE MAINTAINED WITHIN NARROW LIMITS, BOTH ENDS OF WHICH ARE OPEN, AND HAVING MANY PANEL JOINTS SUBJECTED TO DIFFERENTIAL AND CYCLING TEMPERATURE LEVELS. LEAKAGE INTO THE SYSTEM HAS PREVENTED US FROM GETTING BELOW AN EXHAUST RATE OF 178 STD. m^3/min., BUT THE RESULTS WERE WORTH THE EFFORT. IN 1975 TESTS CONDUCTED ON ONE OVEN SHOWED THAT THE TOTAL NATURAL GAS CONSUMPTION OF THE OVEN AFTER-BURNER SYSTEM WAS LESS THAN THE STATISTICAL AVERAGE FUEL REQUIREMENT FOR THE OVEN ABOVE MEASURED IN 1972-73. EXHIBIT 4 SUMMARIZES THESE MATTERS, LISTING THE FUEL CONSUMPTION AS MEASURED IN 1972-73 FOR AFTERBURNER AND OVEN (TIME-WEIGHTED AVERAGES) AT A 227 STD. m^3/min. EXHAUST RATE; 1974 CALCULATED CONSUMPTIONS AT 227 AND 178 STD. m^3/min. EXHAUST RATES; AND 1974 TEST RESULTS OF THE INTEGRATED SYSTEM AND THOSE SAME EXHAUST RATES.

REFERRING TO EXHIBIT 4, FUEL CONSUMPTION RATES WERE CALCULATED FOR AN IDEALIZED, TYPICAL FUME INCINERATOR AND OVEN, LINES 2a AND 2b, ASSUMING 100% PRODUCTION EFFICIENCY. AT 227 m^3/min EXHAUST RATE, THE FUEL REQUIREMENTS CALCULATE TO BE 6.40×10^6 kJ/hr FOR THE INCINERATOR AND 3.68×10^6 kJ/hr FOR THE OVEN. THESE VALUES WERE GENERATED FOR ONE

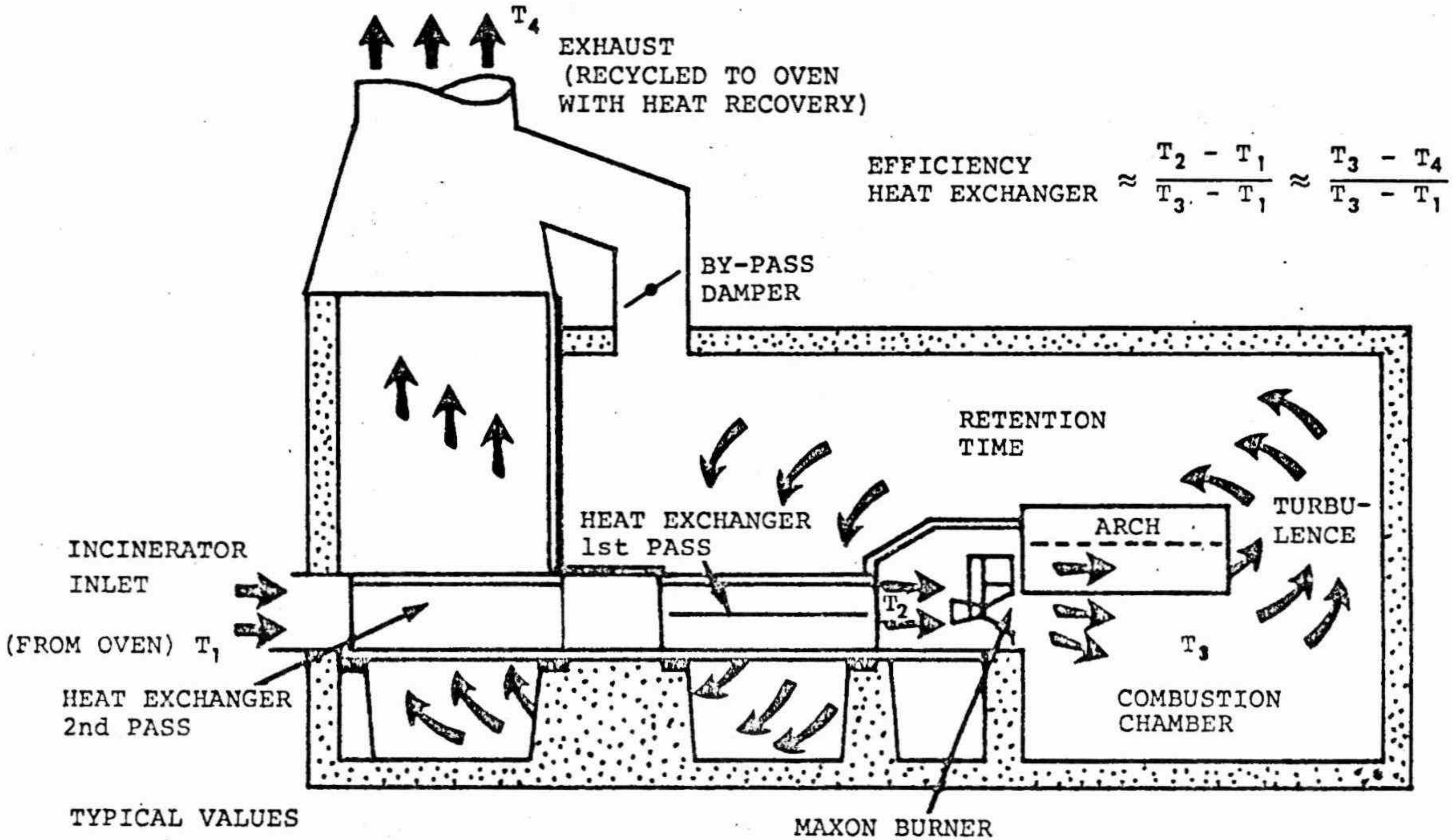
PARTICULAR OPERATING CONDITION, AND WHILE SURPRISINGLY CLOSE TO THE 1973 MEASURED "AVERAGE" VALUES, ARE NOT MEANT TO BE COMPARABLE. THEIR VALUE LIES IN A COMPARISON WITH VALUES CALCULATED UNDER THE SAME CONDITIONS FOR A REDUCED EXHAUST RATE OF 178 m^3/min; NAMELY, 4.31×10^6 AND 3.35×10^6 kJ/hr. FOR INCINERATOR AND OVEN, RESPECTIVELY. THE EXHAUST REDUCTION FROM 229 TO 178 m^3/min. RESULTED IN A CALCULATED FUEL REDUCTION OF 32.7% FOR THE INCINERATOR AND 9.7% FOR THE OVEN, EXHIBIT 4, LINE 2d. NOTE THAT THESE PERCENT REDUCTIONS ARE APPLICABLE ONLY TO ONE PARTICULAR SET OF OPERATING CONDITIONS AND PARAMETERS, AND ARE NOT NECESSARILY APPLICABLE TO THE STATISTICAL AVERAGE FUEL CONSUMPTION RATES.

IN JANUARY, 1974, ONE COMPARISON TEST WAS RUN TO MEASURE FUEL CONSUMPTION RATES. GAS CONSUMPTION RATES WERE MEASURED AT BOTH 227 and 178 m^3/min. EXHAUST RATES AND FOUND TO BE 4.52×10^6 and 3.26×10^6 kJ/hr. RESPECTIVELY, EXHIBIT 4, LINES 3a and 3b. NOTE THAT THESE USAGE FIGURES ARE NOT DIRECTLY COMPARABLE TO THE CALCULATED FIGURES BECAUSE THEY APPLY TO ONE PARTICULAR SET OF OPERATING CONDITIONS. HOWEVER, THE PERCENT REDUCTION IN FUEL CONSUMPTION (27.9%) IS ROUGHLY COMPARABLE TO THE CALCULATED VALUE FOR IDEALIZED CONDITIONS (32.7%)

TWO CONSIDERATIONS ARE PARTICULARLY NOTEWORTHY. FIRST, THE PERCENT FUEL REDUCTION TO BE ATTAINED THROUGH ANY GIVEN EXHAUST RATE REDUCTION IS WIDELY VARIABLE. ITS VALUE IS GREATLY DEPENDENT ON THE PROPORTION BETWEEN THE THERMAL VALUE OF THE SOLVENT LOADING, AND THE FUEL CONTRIBUTION. IN OTHER WORDS, THE GREATER THE VALUE OF THE THERMAL CONTRIBUTION OF THE SOLVENT LOADING, THE GREATER WILL BE THE PERCENT FUEL RATE REDUCTION FOR A GIVEN EXHAUST RATE REDUCTION.

THE SECOND ITEM OF NOTE IS THAT, AT THE REDUCED EXHAUST OF 178 m^3/min., THE INCINERATOR FUEL REQUIREMENT OF 3.26 x 10^6 kJ/hr. IS LESS THAN THE STATISTICAL AVERAGE FUEL REQUIREMENT OF 3.60 x 10^6 kJ/hr MEASURED IN 1972-73. THIS MEANS THAT UNDER CERTAIN SPECIFIC OPERATING CONDITIONS (SOLVENT LOADING), THE FUEL CONSUMPTION OF THE INCINERATOR AND OVEN COMBINATION UNDER HEAT RECOVERY OPERATION CAN BE LESS THAN THE ORIGINAL OVEN REQUIREMENT PRIOR TO INSTALLATION OF THE CONTROL DEVICE. THIS IS OBVIOUSLY NOT TRUE UNDER ALL OPERATING CONDITIONS, AND WAS ARRIVED AT THROUGH CONSIDERATION OF PROPER EXHAUST REDUCTION METHODS. HOWEVER, THE IMPORTANCE OF SUCH A PHENOMENON SHOULD NOT BE MINIMIZED, PARTICULARLY AT LOCATIONS WHERE ADDITIONAL FUEL IS NOT AVAILABLE FOR NECESSARY EMISSION CONTROL DEVICES.

THE EXERCISE HAS HAD A NUMBER OF BENEFITS IN ADDITION TO SAVING WHAT COULD HAVE BEEN A SUBSTANTIAL INCREASE IN THE FUEL BILL. IT HAS SHOWN THAT WE CAN ACCURATELY PREDICT WHAT THE EFFECT OF VARIOUS OPERATING CONDITIONS WILL BE, AND THAT THE PHYSICAL SIZE OF FUTURE AFTERBURNERS CAN BE SUBSTANTIALLY REDUCED. IT HAS ALSO SHOWN THAT FUTURE OVEN DESIGN CAN BE IMPROVED BY REDUCING THE NUMBER OF INDIVIDUALLY CONTROLLED ZONES; AS THE HEAT REQUIREMENT OF SEVERAL EXISTING ZONES IS MINIMAL. MUCH OF THE KNOWLEDGE ACCUMULATED HERE HAS ALSO BEEN USEFUL IN THE DESIGN OF NEXT GENERATION AFTERBURNERS INCORPORATING CATALYTIC ASSIST WHICH NOW APPEARS TO BE PERFECTED.

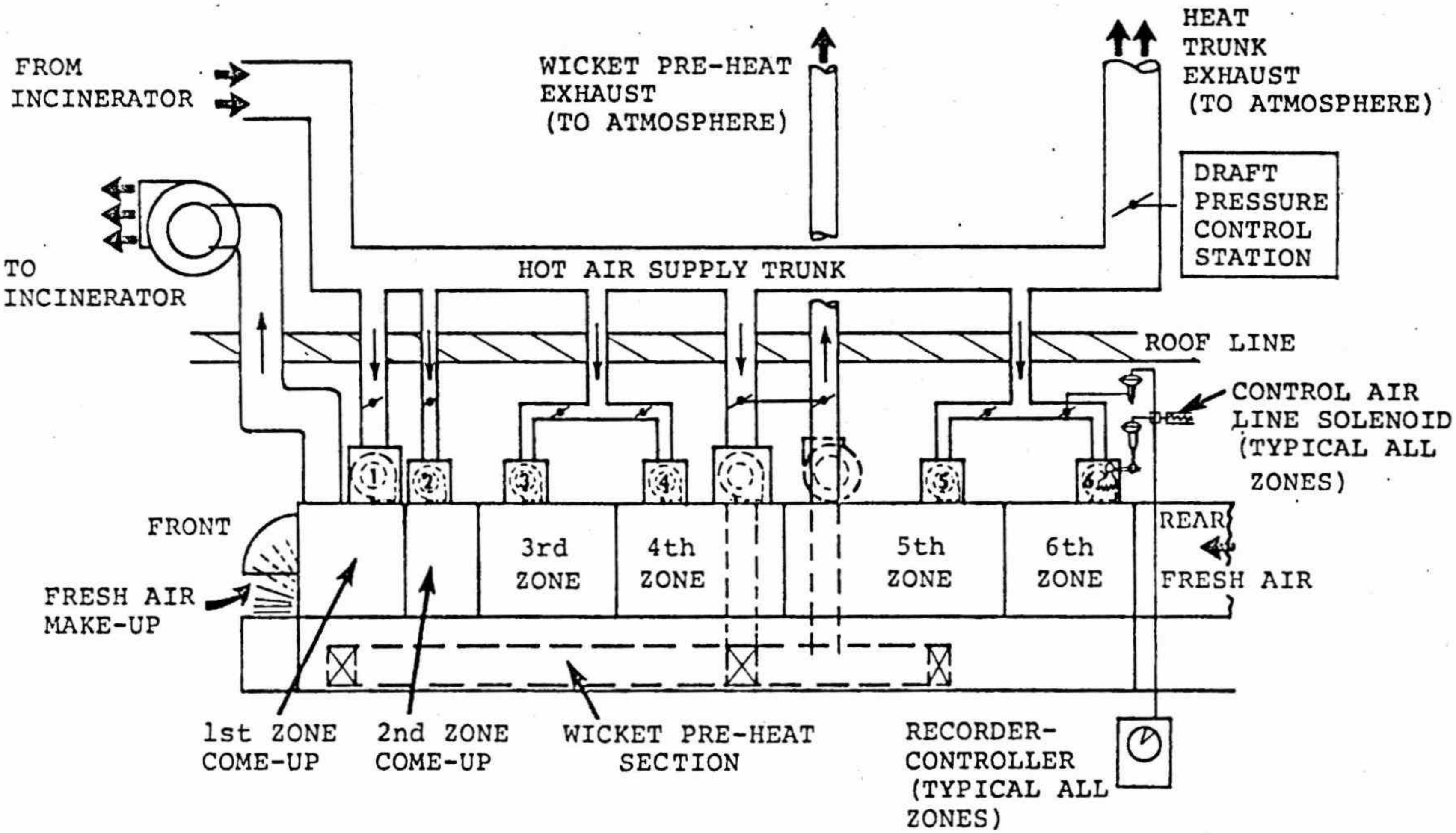


TYPICAL VALUES

T_1 - 280°F (140°C)
T_2 - 780°F (415°C)
T_3 - 1400 °F (760°C)
T_4 - 900°F (480°C)

Heat Exchanger Efficiency - 45%
Exhaust Rate - Approximately
8000 SCFM (227 STD cu m/min)

AFTERBURNER WITH HEAT EXCHANGER..



FROM INCINERATOR
TO INCINERATOR
WICKET PRE-HEAT EXHAUST (TO ATMOSPHERE)
HEAT TRUNK EXHAUST (TO ATMOSPHERE)
DRAFT PRESSURE CONTROL STATION
HOT AIR SUPPLY TRUNK
ROOF LINE
CONTROL AIR LINE SOLENOID (TYPICAL ALL ZONES)
1
2
3
4
5
6
FRONT
FRESH AIR MAKE-UP
3rd ZONE
4th ZONE
5th ZONE
6th ZONE
REAR
FRESH AIR
1st ZONE COME-UP
2nd ZONE COME-UP
WICKET PRE-HEAT SECTION
RECORDER-CONTROLLER (TYPICAL ALL ZONES)

	FLOW RATE STD. m^3/min.	TEMPERATURE ^oC
OVEN EXHAUST	232	99
1ST ZONE	31	438
2ND ZONE	3.1	438
3RD ZONE	1.8	438
4TH ZONE	2.8	438
5TH ZONE	5.4	402
6TH ZONE	ZONE SHUT OFF	402
WPH SECTION	41	427
TRUNK EXHAUST	142	427

TEST CONDITIONS (AUGUST 1972)

EXHAUST RATE:	232 STD m^3/min.
BAKE TEMPERATURE:	171^oC - 8 min.
PLATE SIZE:	74 x 86 cm. - 0.26 mm THICK
SHEET SPEED:	90 SPM
OVEN EXHAUST:	232 STD. m^3/min.
TRUNK:	142 STD. m^3/min.
HOT AIR SUPPLIED TO OVEN:	91 STD. m^3/min. @ 402^oC to 438^oC.

Exhibit 4.

FUEL CONSUMPTION COMPARISON

			FUEL CONSUMPTION RATE (MILLION kJ/hr)		EXHAUST RATE (m^3/min.)
			AFTERBURNER	OVEN	
1.	1972-73 MEASURED				
	"TIME WEIGHTED AVERAGE" FUEL CONSUMPTION (AVERAGED OVER ALL BAKES, OPERATING CONDITIONS, COATING APPLICATIONS AND PRODUCTION EFFICIENCIES)	a.	5.92	3.60	227
2.	1974 CALCULATIONS				
	FUEL CONSUMPTION (FOR IDEALIZED TYPICAL PRODUCTION CONDITIONS, ASSUMED FULL PRODUCTION EFFICIENCY	a.	6.40	3.68	227
		b.	4.31	3.35	178
	DROP IN FUEL CONSUMPTION/EXHAUST RATE	c.	2.09	.33	49
	% REDUCTION	d.	32.7%	9.7%	21.6%
3.	1974 MEASURED				
	FUEL CONSUMPTION SINGLE TEST	a.	4.52	-	227
		b.	3.26	-	178
	DROP IN FUEL CONSUMPTION/EXHAUST RATE	c.	1.26	-	49
	% REDUCTION	d.	27.9%	-	21.6%

THE IMPLEMENTATION OF A DUST CONTROL PROGRAM FOR GRAIN ELEVATORS IN THUNDER BAY

Saskatchewan Wheat Pool operates ten Terminal Grain Elevators in Thunder Bay, Ontario, which annually handle up to 300 million bushels of grain, about 35 per cent of the Canadian export volume. Since 1972 the Company has been involved in a major program to control dust emissions from these elevators.

There are twelve Saskatchewan Wheat Pool Elevators with about 1000 individual emission points discharging a total volume of five million CFM.

For the most part the methods of removing particulate matter from the air streams by use of fabric filters was well established. The main task of this undertaking was to provide economical, dependable systems, compatible with operating requirements and to do this in existing facilities.

Forty per cent of the program described is to be completed by year end and the remainder by the end of 1977.

by

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A native of Shoal Lake, Manitoba, Mr. Stone graduated from the University of Manitoba in 1955 with a Bachelor of Science in Mechanical Engineering. He is a member of the Association of Professional Engineers of Ontario and the Grain Elevator and Processing Society. Prior to working in the grain industry he was involved in Plant Engineering in a Chemical Fertilizer Plant and also in Petroleum Engineering in Alberta. As Project Engineer with Saskatchewan Wheat Pool he is now responsible for the Dust Control Program at Their Thunder Bay Elevators.

THE IMPLEMENTATION OF A DUST CONTROL PROGRAM FOR GRAIN ELEVATORS IN THUNDER BAY

by

B. D. Stone

I INTRODUCTION

This paper describes the Dust Control Program undertaken by Saskatchewan Wheat Pool in its grain elevators in Thunder Bay, and covers both the overall program and a more detailed description of the projects underway at individual elevators.

In July 1969 owners of grain elevators in Thunder Bay were approached by the then Air Management Branch regarding excessive emission of grain dust. This was the beginning of what was to be a ten year, 30 million dollar program to reduce dust emission. In order to understand the problems more fully an overview of our industry and some of the background information on dust sources and emissions might be useful.

Thunder Bay is one of the world's busiest grain ports. The statistics pertaining to its grain handling ability are impressive and include:

- an annual throughput capacity of 600,000,000 bushels
- a railcar unloading capacity of 1800 cars per day or 300,000 cars per year
- a grain storage capacity of 95,000,000 bushels
- annual loading of 700 ships

This slide will give you a better idea of the type of facilities we're considering. It shows a group of 7 of the Lakehead's 19 active elevators.

There are two classes of dust sources in an elevator. The first is grain cleaning and is a situation unique to the Canadian Handling System. Unlike most other countries we ship extremely clean, highly graded grain which is accomplished by precise cleaning at terminal points such as Vancouver and Thunder Bay. A fundamental procedure in cleaning grain is aspirating the grain with an air stream to remove dust and chaff. This is

accomplished on small, low capacity cleaners, using 5000-10,000 CFM of air. This accounts for about 50% of our dust control problem.

The second source of air emission is from dust control systems serving points where the grain stream is transferred to or from conveyors, bins or spouts. Between entering and leaving the elevator grain will pass through 20 to 30 different transfer points which each have aspirated hoods or enclosures to suppress dust.

All dust from the grain cleaners and from dust control systems was originally controlled by cyclone dust collectors.

These slides shows the cyclones at our #7 elevator before the present dust control program began. There are about 130 separate cyclones with a total air discharge of 850,000 CFM. You can also visualize their efficiency as dust collectors by the amount of dust being discharged.

II DEFINITION OF DUST CONTROL REQUIREMENTS

After first being approached by the Air Management Branch the elevator owners formed a committee within the Lakehead Terminal Elevator Association. This committee worked with the Air Management Branch from 1969 to 1972 to define the extent of the dust emission problem and suitable methods and schedules for control.

One of the most crucial items at the outset of this program was to define the quantities of air and dust being discharged. The dust control systems in the elevators had been in service for periods of between 20 and 70 years and very little information was available on air volumes, dust loadings and cyclone efficiency.

The initial effort was directed at determining the air volumes being discharged from each point in each elevator. This required running a pitot tube traverse on about 2000 individual points in 23 separate elevators.

Table #1 summarizes the measured volumes for each elevator. The magnitude of the volumes indicates the scope of the problem.

A second survey was carried out to determine dust quantities generated and cyclone effiency for each type of operation. This consisted of simultaneous high volume sampling of cyclone inlets and discharges. A total of 35 tests were run on 15 separate cyclones. Table #2 summarizes the survey results. Under the column "Operation" is a sequential list of each operation a batch of grain encounters as it passes through the elevator. The second column gives the average cyclone efficiency and the third shows the measured amount of dust generated per ton of grain handled. The fourth and fifth columns indicate the portion of dust collected by the dust collectors and the portion discharged to the atmosphere. The final total shows .703 lbs. of dust are emitted to the atmosphere per ton of grain handled.

After both the air and dust measurements surveys were completed we combined the results to determine the relative costs of reducing dust emissions from each type of system. Table #3 shows these costs, and was used as an input to develop the overall program. As I'll discuss later the garner and scale vents were the first points to be fully controlled, principally, because 35% of the total dust being emitted was collected by filtering about 6% of the air.

The meetings with the Air Management Branch resulted in Control Orders being issued to the elevator companies in May 1972.

After receiving these Saskatchewan Wheat Pool prepared an overall program for dust control in the 12 elevators we then operated. Table #4 shows the preliminary schedule and our estimated costs at that time.

Some of these elevators were older facilities located in relatively poor positions in the harbour. The large dust control expenditures necessitated

TABLE NUMBER 1
****

AIR VOLUME SURVEY
ALL THUNDER BAY ELEVATORS

TOTAL AIR DISCHARGE VOLUMES (CFM)

ELEVATOR	VOLUME (CFM)
Sask. Pool 4A	466,316
Sask. Pool 4B	426,215
Sask. Pool 5	451,452
Sask. Pool 6	571,604
Sask. Pool 7	790,637
Sask. Pool 8	270,832
Sask. Pool 10 (5F)	162,810
Sask. Pool 11	171,042
Sask. Pool 14	322,641
Sask. Pool 15	375,831
Sask. Pool 16	409,381
Sask. Pool 17	377,263
Alta. Pool 9	201,215
Man. Pool 1	536,895
Man. Pool 2	163,625
Man. Pool 3	416,939
U.G.G. A	652,418
U.G.G. McCabe	394,740
Richardson A	537,722
Richardson B	173,677
National	324,069
P & H	114,696
	8,312,020

BASED ON: Lakehead Terminal Elevator Air Volume Survey, February 1971

TABLE NUMBER 2
****

RESULTS OF DUST SAMPLE SURVEY

OPERATION	CYCLONE EFFICIENCY %	DUST GENERATED LB/TON OF GRAIN	DUST COLLECTED LB/TON	DUST DISCHARGED TO ATM. LB/TON
Railcar dumping	88.7	0.3334	.2955	.0379
Garner & scale	No cyclone	0.10	0.0	.100
Cleaner bin	90	0.03	.027	.003
Cleaning #1	91.4	1.454	1.330	.124
Garner	No cyclone	.05	0.0	.05
Cleaning bin	90	.03	.027	.003
Cleaning #2	91.4	1.454	1.330	.124
Garner	No cyclone	.05	0.0	.05
Belt loader	74.15	.03325	.02465	.0086
Belt tripper	74.15	.03325	.02465	.0086
Annex storage bin		.00	0.0	0.0
Shipping belt loader	74.15	.03325	.02465	.0086
Fixed tripper and Leg boot	74.15	.03325	.02465	.0086
Garner & scale	No cyclone	.05	0.0	.05
Shipping bin	No cyclone	.03	0.0	.03
Railcar loading	83.25	.1505	.1253	.0252
Subtotal		3.8649	3.2334	.6315
Main Dust Transportation System	97.8	3.2334	3.1624	.071
TOTAL		3.2334	3.1624	.703

BASED ON: Lakehead Terminal Elevator Association Dust Sampling Survey, July 1971

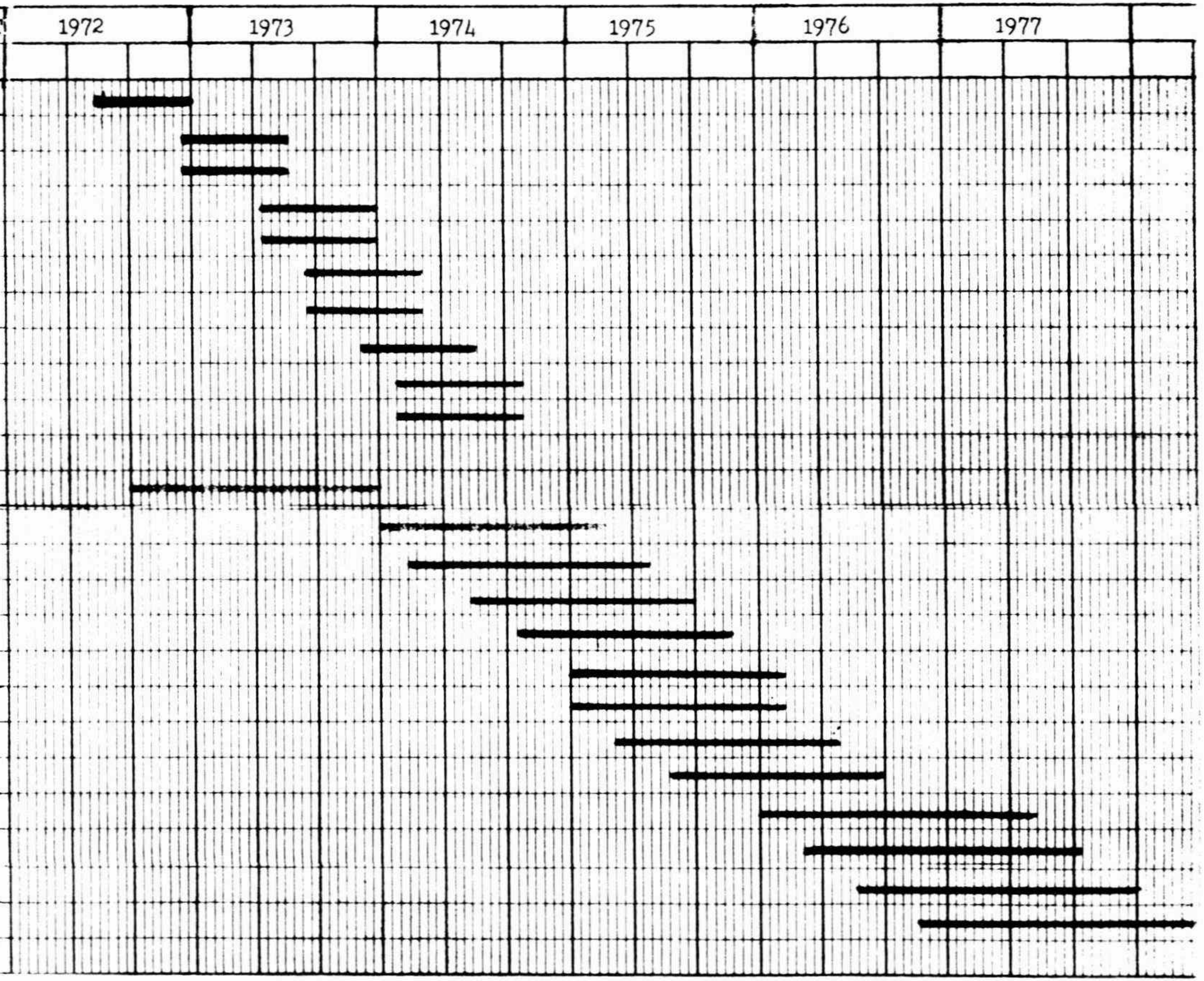
TABLE NUMBER 3
****

RELATIVE COSTS TO COLLECT AND FILTER
DUST EMISSION FROM VARIOUS OPERATION

OPERATION	1 RELATIVE AMOUNTS OF DUST TO BE COLLECTED	2 TYPICAL AIR VOLUME (CFM)	3 RELATIVE COST $\doteq \frac{2}{1} \times 10^{-3}$
Garner & Scales	.250	25,000	100
Main Dust Transportation	.071	10,000	140
Workhouse Bins	.036	15,000	417
Cleaners	.248	200,000	806
Railcar Dumping	.038	80,000	2105
Clean Grain Transfer To Annex	.036	100,000	2777

PRELIMINARY SCHEDULE AND ESTIMATED COST
MAY 1972
****

ELEVATOR	ESTIMATED COST
PHASE I-SCALE AND GARNER VENTS	
INITIAL TESTING	
#7	$ 97,000
#14	47,000
#6	84,000
#17	75,000
#4A	86,000
#4B	73,000
#16	65,000
#5	87,000
#15	54,000
PHASE II-FULL DUST CONTROL	
PREPARE PARAMETERS	
#14	$1,114,000
#7	2,600,000
#6	2,370,000
#15	1,270,000
#4A	1,710,000
#4B	1,570,000
#16	1,790,000
#5	1,770,000
#8	1,000,000
#17	1,835,000
#10	880,000
#11	990,000
TOTAL	$19,567,000



a very careful look at their future role in our system and of the 12 elevators we were forced to decide on abandonment and demolition of five. We expect the total demolition costs to reach about $ 1,500,000.

Our overall dust control program was then reduced to a more manageable size, covering 7 elevators. Table #5 summarizes the program for these plants showing first garner and scale vents and second what we term Phase II, full dust control, with air volumes, and costs for each phase. This is the actual program undertaken, and now about 30% complete.

I'd now like to describe how we implemented this program and give specific examples of some of the more novel ideas we've used, describe the equipment selected, and then touch on costs.

On all projects we made extensive use of consulting engineers to work on what might best be termed a modified project management approach based on detailed design parameters prepared by Saskatchewan Wheat Pool. This approach entails a detailed survey of each area of work, system design, individual selection of all major equipment, and detailed design and construction responsibilities. This is admittedly an expensive approach to engineering but we felt it was the only method which would insure an adequate overall design, individual selection of major equipment, and competitive supply and installation pricing.

III PHASE I - SCALE AND GARNER VENT CONTROLS

Preliminary surveys had shown garner and scale vents were responsible for about 35% of the total dust emission but required filtering only 6% of the air (and therefore representing about 6% of the costs). Also, these emission points were the highest points on the elevators and were the most visable. Figure 1A is a cross section of an elevator showing the vent location.

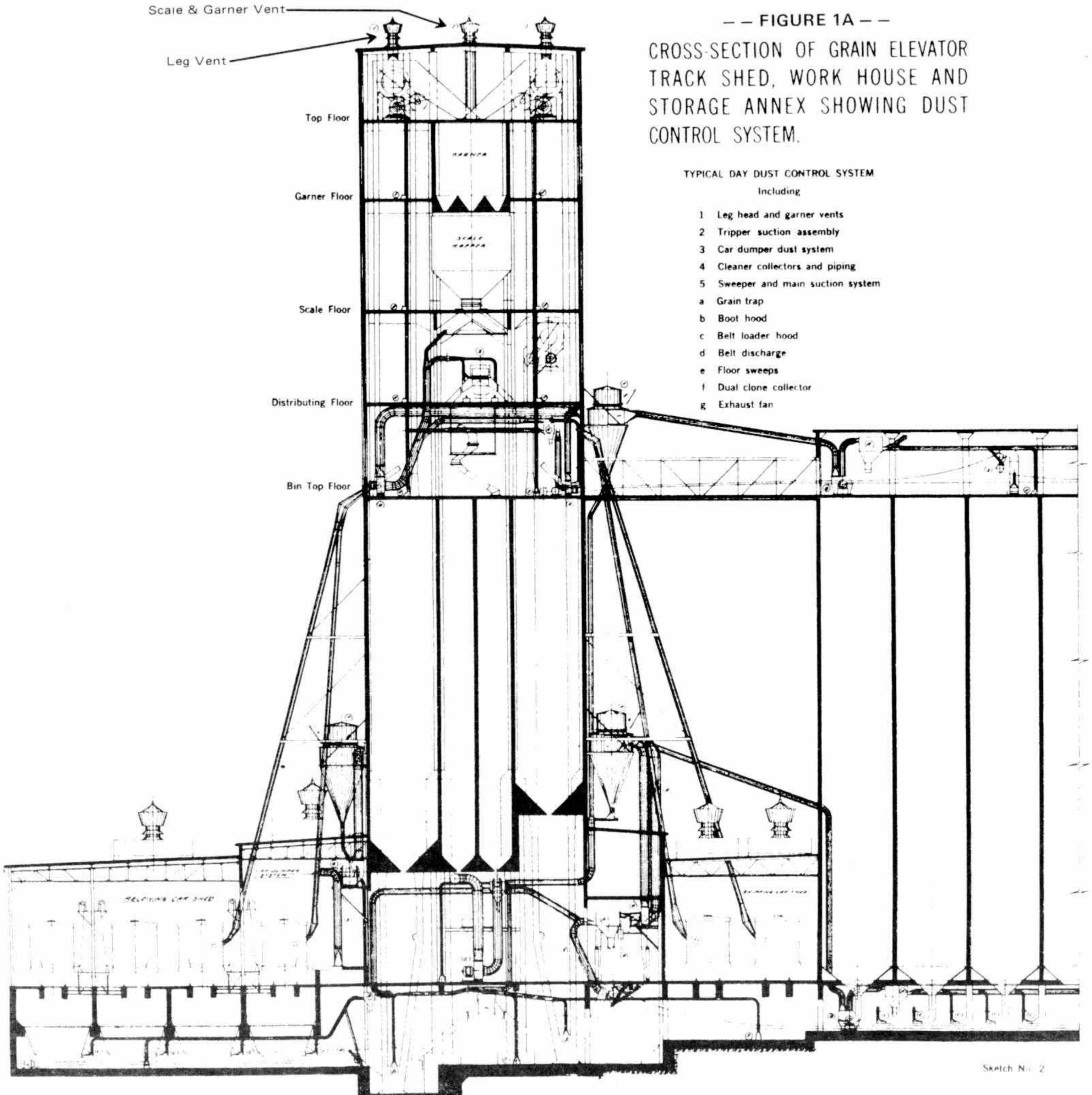
TABLE #5

SASKATCHEWAN WHEAT POOL (SWP)
FINAL DUST CONTROL PROGRAM
****

PROJECT	AIR VOLUME FILTERED (CFM)	COST
PHASE I - SCALE AND GARNER VENTS		
SWP ELEVATOR 4A	27,800	$ 92,000
SWP ELEVATOR 4B	24,500	95,000
SWP ELEVATOR 6	27,500	102,000
SWP ELEVATOR 7	43,000	115,000
SWP ELEVATOR 14	18,000	47,000
SWP ELEVATOR 15	16,350	73,000
TOTAL	157,150	$524,000
PHASE II - FULL DUST CONTROL		
SWP ELEVATOR 4A & 4B	853,000	$ 4,380,000
SWP ELEVATOR 6	486,000	3,137,000
SWP ELEVATOR 7	730,000	3,249,000
SWP ELEVATOR 8	270,000	1,420,000
SWP ELEVATOR 14	310,000	1,669,000
SWP ELEVATOR 15	381,000	2,341,000
TOTAL	3,030,000	$16,196,000
TOTAL	3,187,150	$16,720,000

— — FIGURE 1A — —

CROSS-SECTION OF GRAIN ELEVATOR TRACK SHED, WORK HOUSE AND STORAGE ANNEX SHOWING DUST CONTROL SYSTEM.



TYPICAL DAY DUST CONTROL SYSTEM
Including

1 Leg head and garner vents
2 Tripper suction assembly
3 Car dumper dust system
4 Cleaner collectors and piping
5 Sweeper and main suction system
a Grain trap
b Boot hood
c Belt loader hood
d Belt discharge
e Floor sweeps
f Dual clone collector
g Exhaust fan

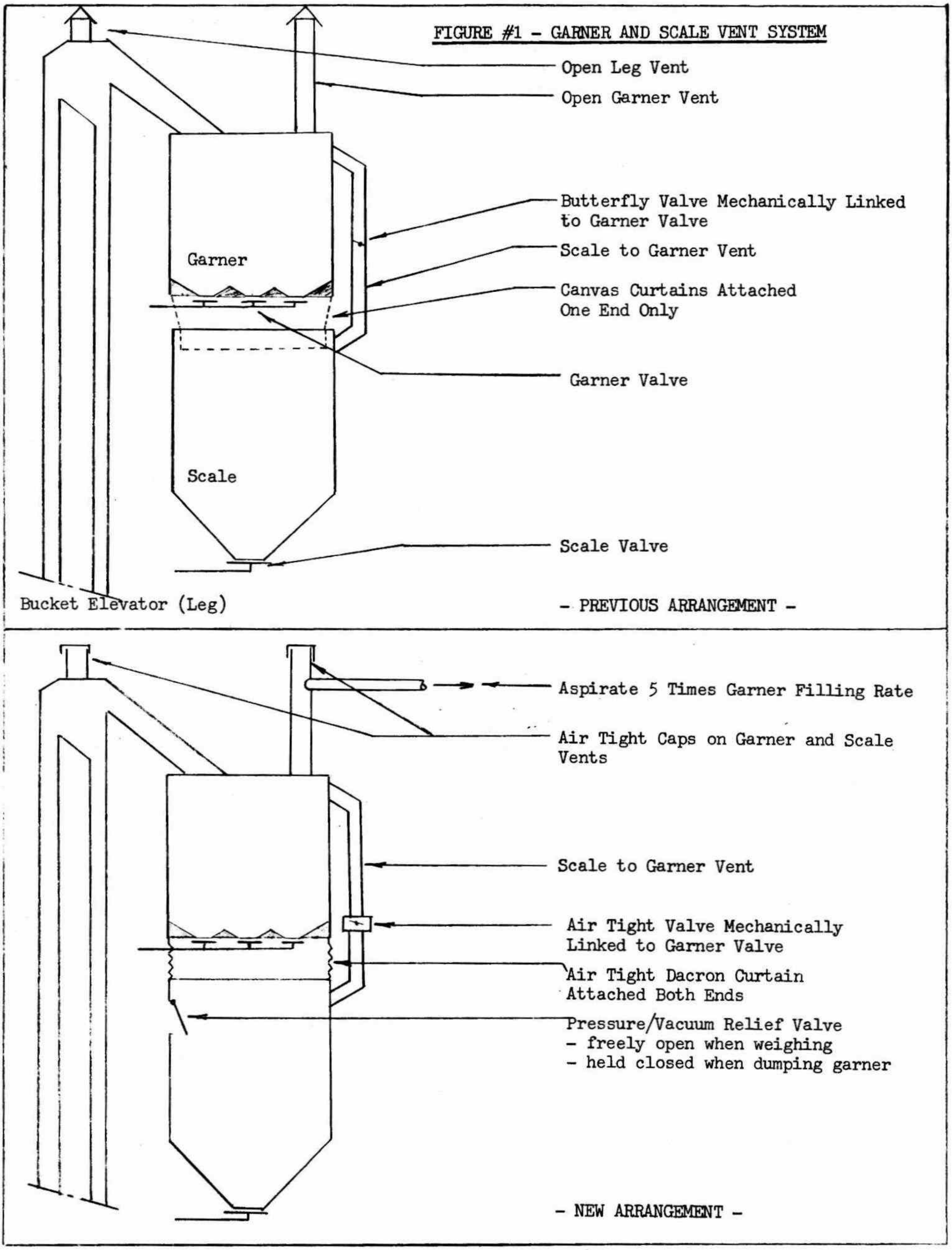
The first phase of our program was therefore to control dust emissions from these. This slide shows an open vent before dust control was installed and shows the amount of dust discharging and accumulated around it. The second slide shows the roof of one of our elevators after dust control was installed. We have now controlled a total of 125 vents at 6 elevators at a cost of $524,000 and collect about 5 tons/day of dust.

Figure #1 shows the process we are considering. As the bucket elevator feeds the garner air is displaced out the open vent in proportion to the amount of grain entering. We did considerable testing in this area and came up with some surprising facts; For example, you might expect that for each cubic foot of grain fed into the garner a cubic foot or slightly more air would be displaced, but our measurements showed large amounts of air are induced with the grain into the garner, at least 4 cubic feet of air for every cubic foot of grain. Also we found that if an open vent was left on the leg head, which had been the normal practice, additional air was induced, raising the ratio from 4:1 to about 8:1.

Figure 1 also shows the final design, which was simply to cap both leg and garner vents and to aspirate an air volume from the garner of about 5 times the grain filling rate. Final filtering is carried out on fabric filters using 16 oz. dacron filter cloth at an air cloth ratio of about 9:1.

Another design problem encountered was at the scale. The garner is dumped into the scale at a rate of 2000 bushels in one minute or 2500 cubic feet per minute. The air displaced is vented back into the garner and replaces the grain volume, which causes no additional air discharge from the garner. To prevent dust blow-back at the garner scale interface dacron curtains are attached to both the garner and scale. This air tight curtain can however allow pressure or vacuum to build up within the scale which affects scale. We are required to weigh within 15 lb. per 100,000 lb. and pressure

FIGURE #1 - GARNER AND SCALE VENT SYSTEM



changes greater than .005 inches water column can not be tolerated.

To prevent any pressure buildup vents are installed on the scale which are open when grain is weighing and closed when dumping the garner into the scale. Attaching any device to the scale poses a difficult design problem as the least force will alter the scale readings and we are particularly proud of the simplicity of the design finally used. It is a counter weighted damper which hangs freely open when the garner valve is shut and weighing is taking place and is forced closed by an open garner valve.

IV PHASE II - FULL DUST CONTROL

1. DEFINITION

After completion of the garner vents, although we had caused a significant decrease in dust discharge, we had to address ourselves to the much more complex and costly task of filtering all or at least most of the air being discharged.

The Control Orders issued by the Air Management Branch limited dust discharge from each elevator to an amount that would produce less than 15 tons per square mile dustfall per month and less than 100 micrograms per cubic meter suspended particulate both at our property line. We had a fairly accurate picture of conditions within the city and around the elevators through several years of air quality readings taken by the Air Management Branch. Our calculations (I should really say estimation) was that a total reduction in dust emission of about 90% would be required to meet these standards. This led to a decision to filter all air discharge except the annex dust control. This slide shows cyclones serving these annex systems on our #7 elevator. Our surveys had indicated they accounted for only 2½% of dust emissions but represented over 10% of the cost. Also as you can see they are relatively isolated systems and would require individual filter systems in any case. Our program has proceeded in this manner with the

knowledge that in the final analysis we may be required to filter the air from the annexes to meet the standards.

2. PRELIMINARY DESIGN PHASE

As a preliminary design stage we surveyed all internal dust control and grain cleaner systems to define the modifications necessary to bring these up to present day standards, and to optimize air consumption.

Grain cleaners accounted for about 50% of our air volume and thus 50% of the costs. In the past the need for aspiration in the grain cleaning process had been adequately met by using ample if not excessive volumes, which was acceptable, as extra dust control costs for a larger cyclone and duct were small. By carefully analyzing the aspiration process in the cleaners the design air volume was cut from 7500 to 5000 CFM in one third of the cleaners representing a total saving to Saskatchewan Wheat Pool of about 120,000 CFM. Also by carefully analyzing our cleaning needs we found that by replacing 30 sieve type cleaners which used 10,000 CFM each, with indent cleaners using 5000 CFM each, we could not only save some 150,000 CFM but could increase our cleaning capacity.

We also investigated all areas of dust control within the elevators resulting in some noticeable changes in our design, especially for conveyor belts and for bins. Figure 2A is a cross section of an elevator showing the workhouse bins. Previously the workhouse bins were individually aspirated at a design rate of about 400 CFM per bin. This rate was marginally enough for most filling rates, but the systems were unreliable and ineffective. Figure #2 shows typical dust control for both the previous and new systems. The system is such that at Pool #7 for example, 140 bins are fed from 26 different scale or garner discharges, meaning a maximum of 26 bins need be aspirated at once. In the original design each bin was aspirated individually, and the system was sized to handle only a portion of the bins at once. There was no method of selecting bins, and the design relied on lack of air supply in unused bins

— — FIGURE 2A — —

CROSS-SECTION OF GRAIN ELEVATOR TRACK SHED, WORK HOUSE AND STORAGE ANNEX SHOWING DUST CONTROL SYSTEM.

TYPICAL DAY DUST CONTROL SYSTEM
Including

1 Leg head and garner vents
2 Tripper suction assembly
3 Car dumper dust system
4 Cleaner collectors and piping
5 Sweeper and main suction system
a Grain trap
b Boot hood
c Belt loader hood
d Belt discharge
e Floor sweeps
f Dual clone collector
g Exhaust fan

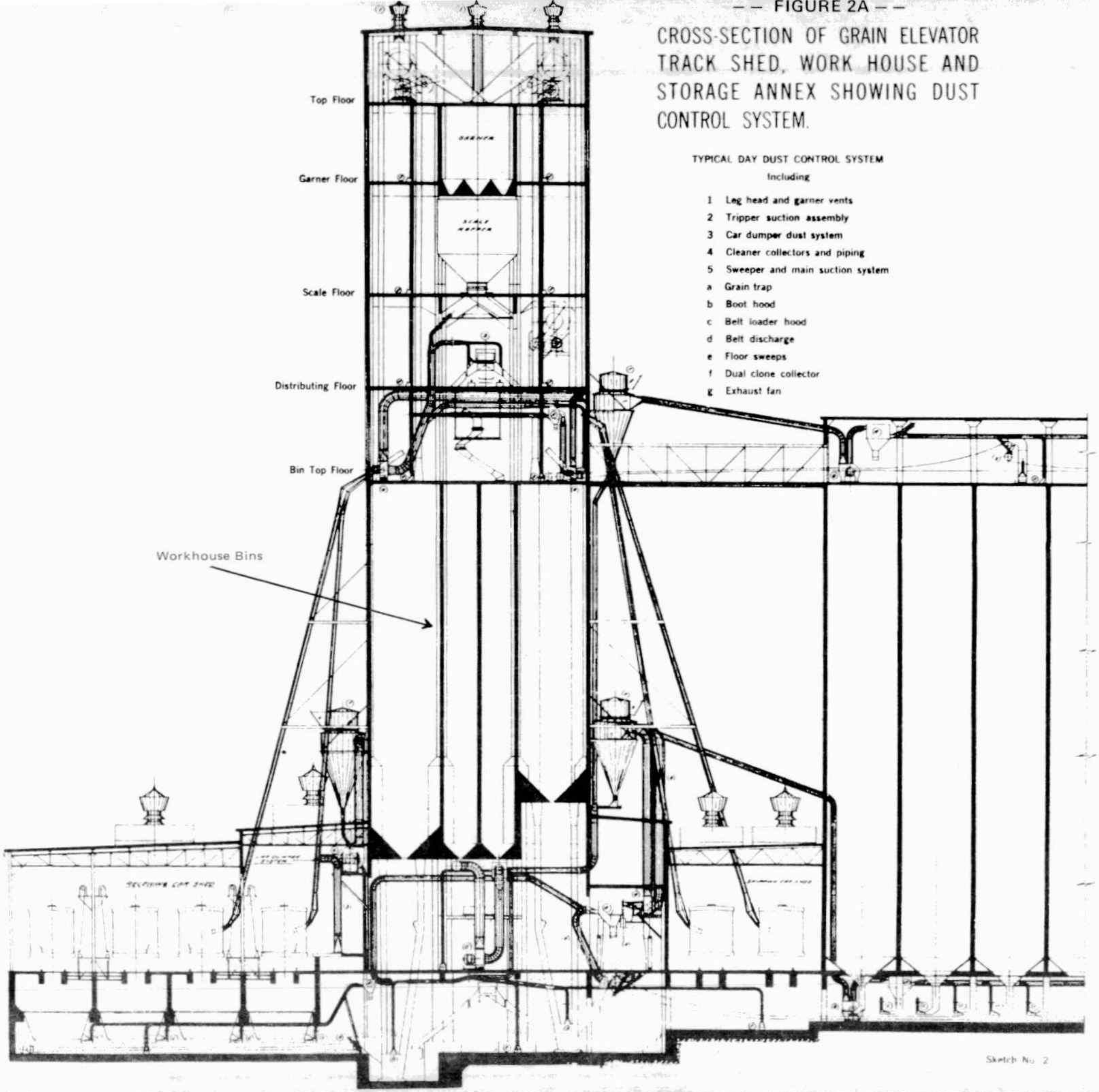
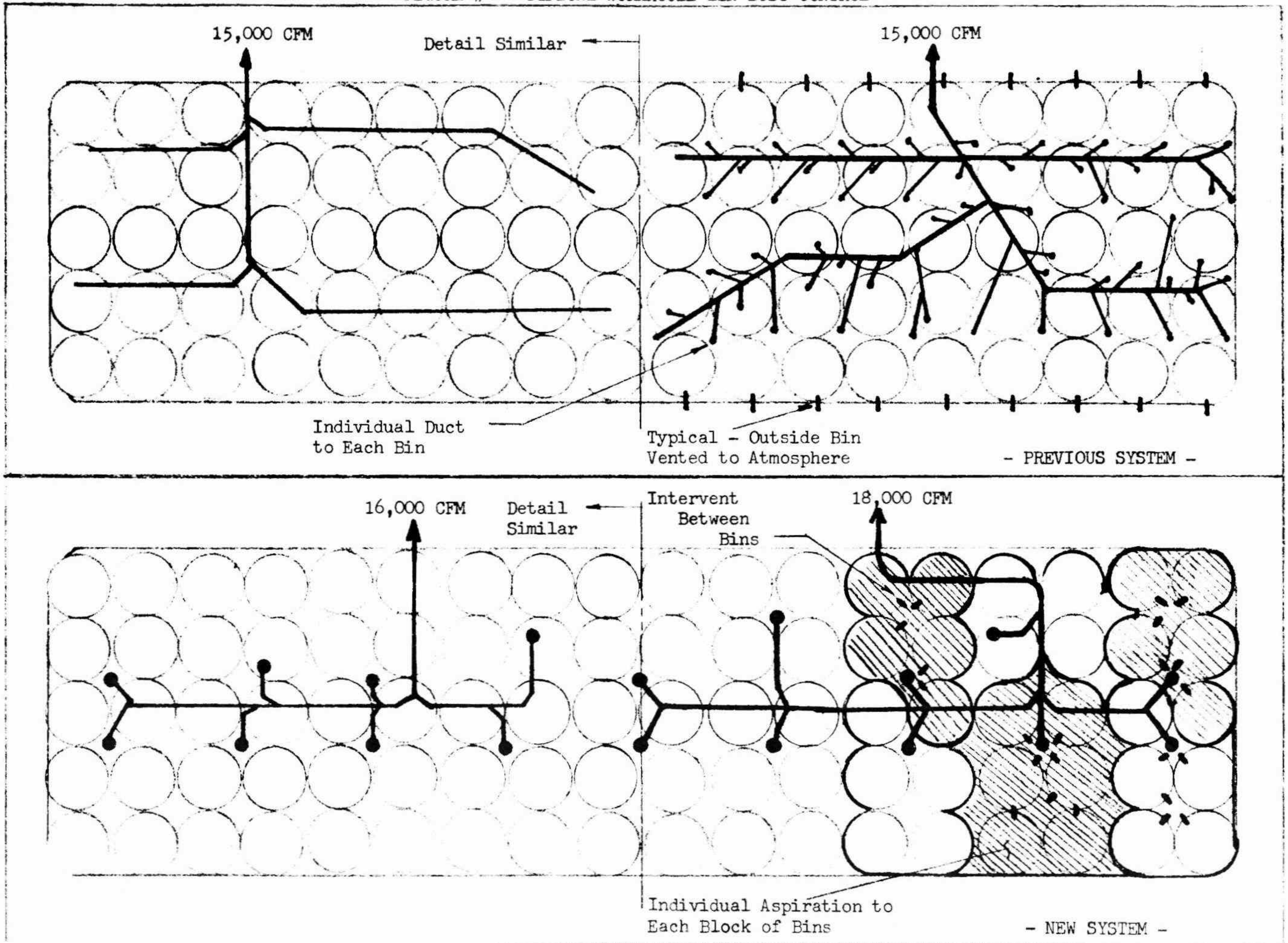


FIGURE #2 - TYPICAL WORKHOUSE BIN DUST CONTROL



to regulate air flows. This doesn't work as many of the ducts quickly plug and the system soon became ineffective.

We now have divided the plants into blocks of bins and use a single large duct to aspirate each block with the bins intervented into each other to allow air dispersion. This is much more effective and reliable than the original system.

Conveyor belts are one of the chief sources of dust within an elevator. Dust is generated at the loader when grain is fed onto the belt, and at the head pulley or tripper where grain leaves the belt, plus all along the moving belt.

In the past dust control consisted of aspirated hoods at each loader point, an aspirated hood above the head or tripper pulley and an aspirated belt wipe at each head and tripper pulley. Our new approach is as shown on Figure #3. We first run continuous hooding over exposed portions of the belt wherever possible and secondly, install more effective loader hoods and head pulley dust control.

These are a few examples of the work carried out in the preliminary design phase, which represented about 2% of the overall project costs and required 6 months to complete in each elevator. The end result was a flow diagram of each air system defining flow paths, volumes, and duct sizes. Figure #4 shows one of the 30 separate flow systems for our elevator #7.

3. DESIGN PHASE

After completion of this preliminary phase defining the flow requirements we entered what we termed the design phase where equipment was selected and drawings and specifications prepared. I'd like to go into some detail on the selection of filters and fans and then to mention briefly the selection of auxiliary systems such as compressed air, power supply, controls and dust disposal.

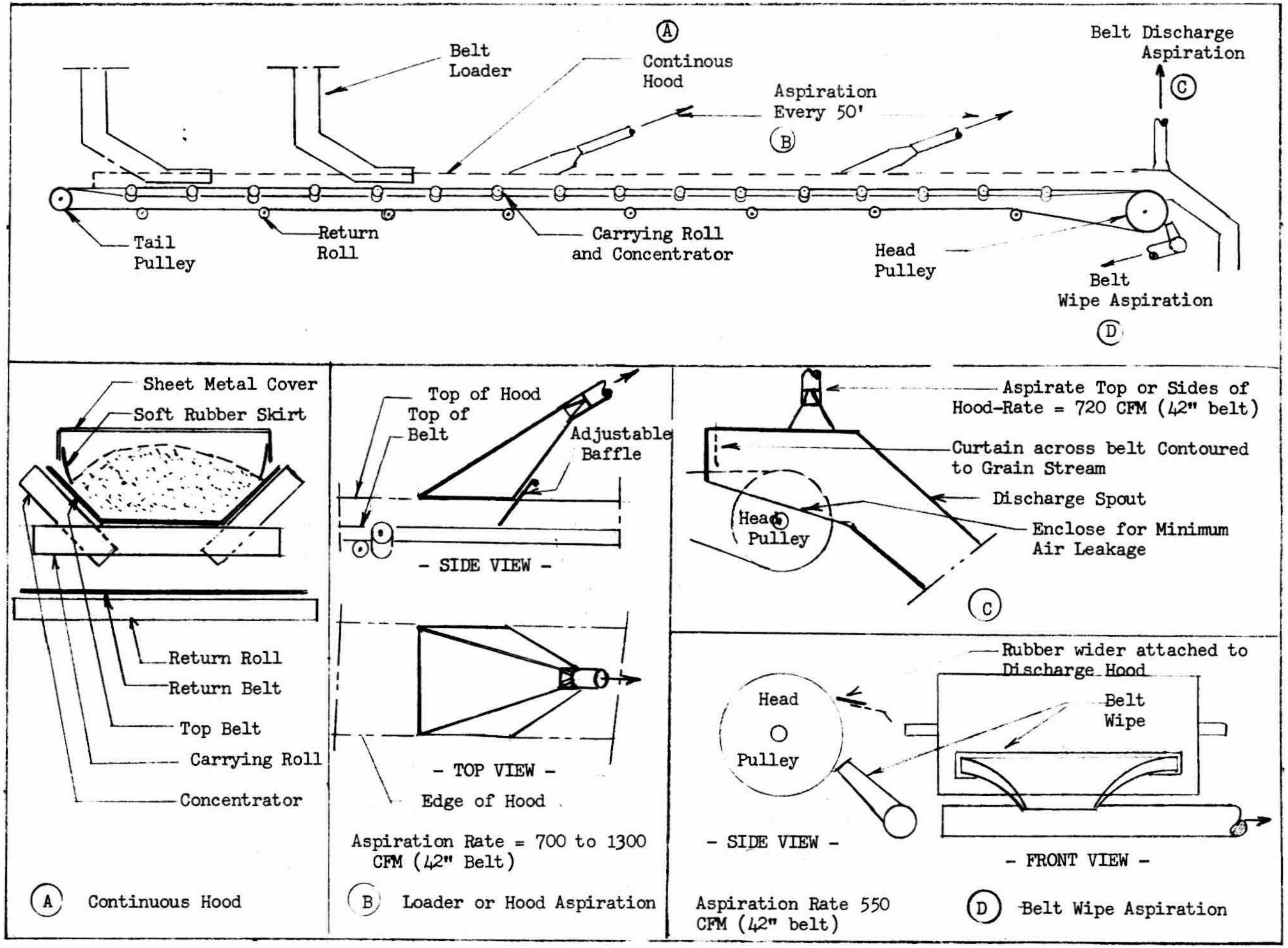


FIGURE #3 - CONVEYOR BELT DUST CONTROL

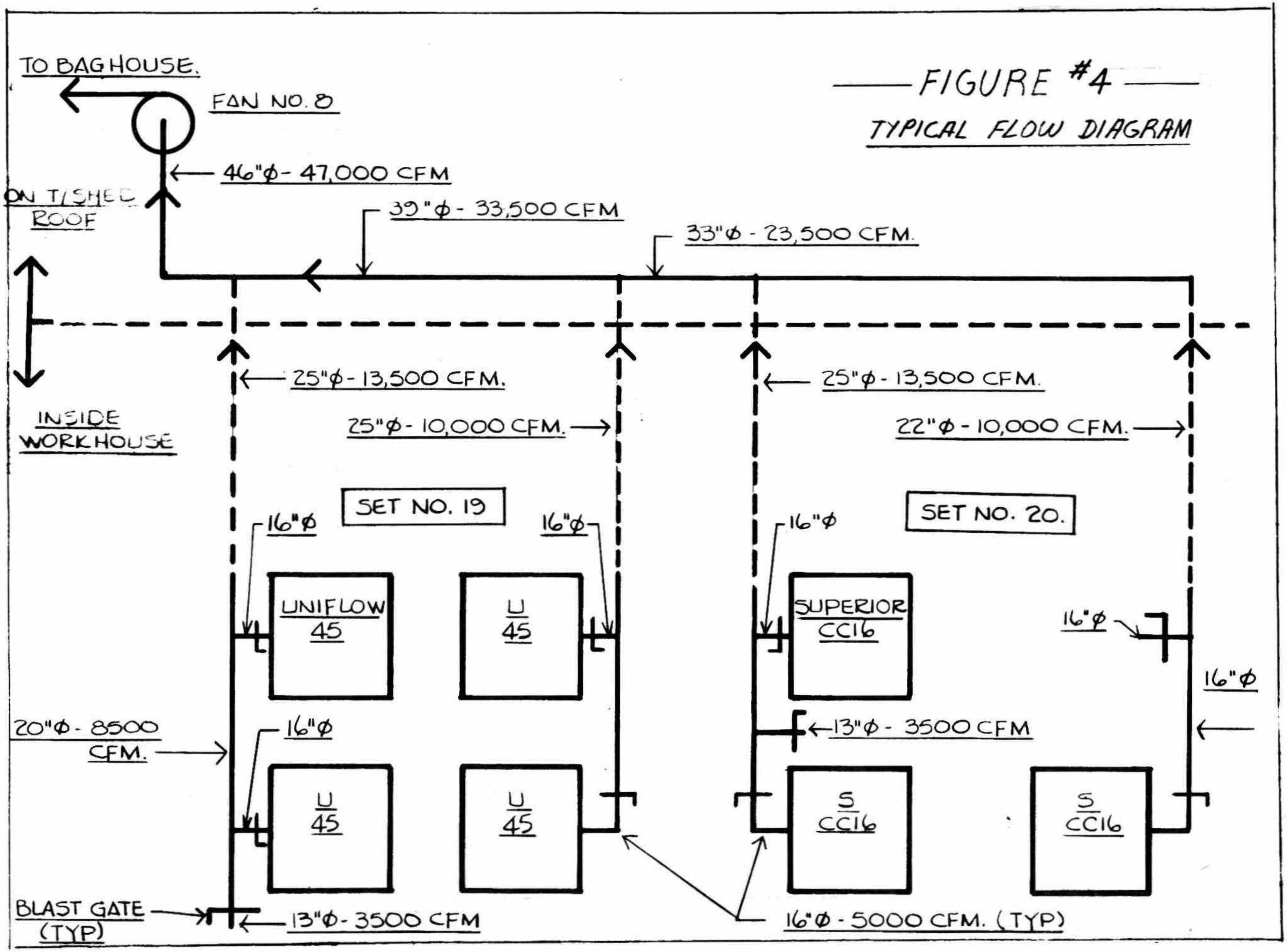


FIGURE #4

TYPICAL FLOW DIAGRAM

FILTERS

For each elevator filters were selected on competitive tenders based on our specifications. We used a reasonably broad specification which allowed combinations of filters ranging from an individual filter for each fan system to a single filter serving all fan systems.

There are basically three types of filters allowed by our specifications, as indicated on Figure #5. These are:

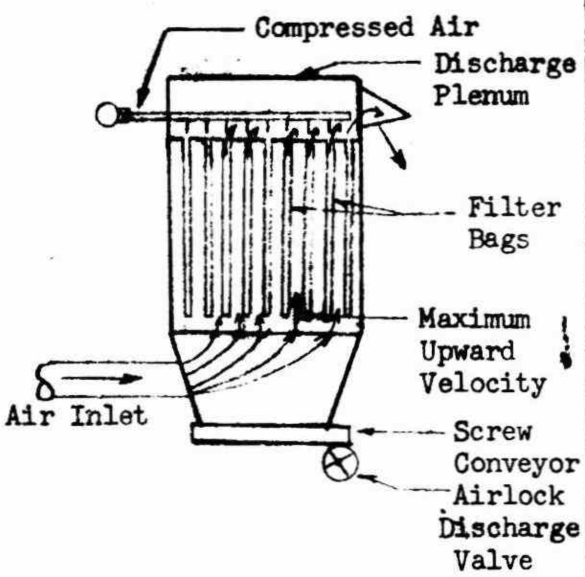
Type A - high ratio, cleaned by reversed jets of compressed air, Type B - high ratio, cleaned by reverse low pressure air, and Type C - low ratio shaker units. Our basic performance criteria is that the pressure drop across the filter material is not to exceed 4" of water column after 1 year of operation and that filtering efficiency is to exceed 99.9%.

Our air cloth ratio and filter material requirements are reasonably standard but the one additional criteria we specify is a maximum upward velocity for bottom inlet type units. Bottom inlets have an important economic advantages both in construction and installation costs but we are concerned about the re-entrainment problems caused by high upward air velocities between the filter bags.

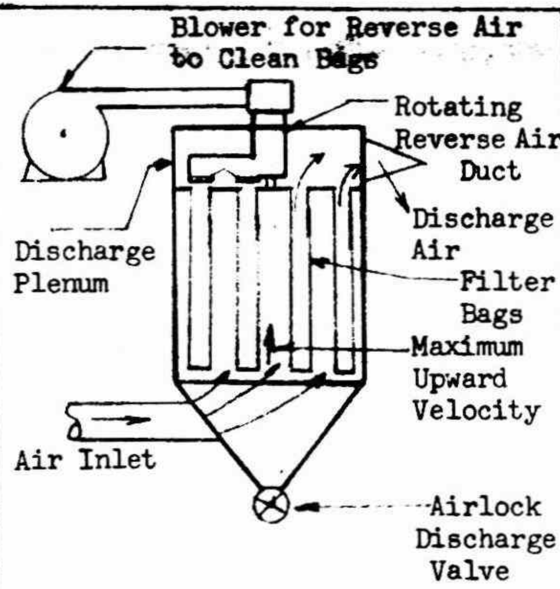
Upon receipt of tenders we make a detailed analysis of each proposal and select all those meeting our requirements. Each of these is compared on a total cost basis, including capital cost and future operating costs. Table #6 shows a typical analysis.

There are quite a number of factors to take into account: first the bid price which can reflect market conditions as well as construction.

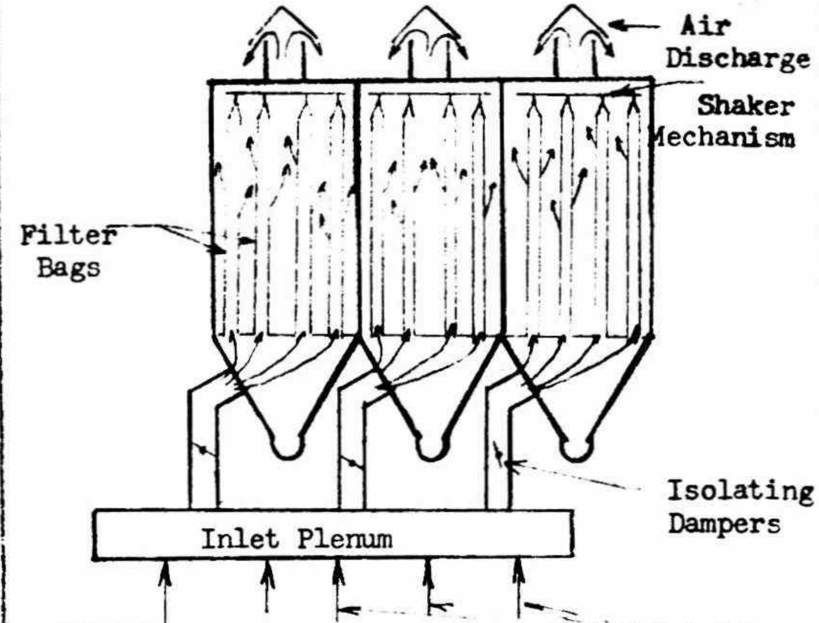
Secondly, the items shown under associated installation costs are comparable costs to install the units and purchase associated systems. Significant items to look for here are:



- TYPE A -
HIGH/RATIO - CLEANED BY REVERSE COMPRESSED AIR



- TYPE B -
HIGH/RATIO - CLEANED BY REVERSE LOW PRESSURE AIR



- TYPE C -
LOW RATIO SHAKER UNIT

TYPE A

MAXIMUM AIR CLOTH RATIO
- Dust loading to 5 gr./ft^3 - 10:1
- Dust loading to 20 gr./ft^3 - 6:1
- Dust loading to 200 gr./ft^3 - 4:1

MAXIMUM UPWARD VELOCITY
- 350 ft./min.

FILTER MATERIAL
- polyester needled felt
- 15 to 17 oz. per sq. yd. weight
- 20 to 35 CFM per sq. ft. permeability at ½" W.C.

PRESSURE DROP ACROSS BAGS
- maximum 4" W.C. after 1 yr. operation

FILTERING EFFICIENCY
- minimum 99.9%

TYPE B

MAXIMUM AIR CLOTH RATIO
- Dust loading to 5 gr./ft^3 - 10:1
- Dust loading to 20 gr./ft^3 - 6:1
- Dust loading to 200 gr./ft^3 - 4:1

MAXIMUM UPWARD VELOCITY
- 350 ft/min.

FILTER MATERIAL
- polyester needled felt
- 15 to 17 oz. per sq. yd. weight
- 20 to 35 CFM per sq. ft. permeability at ½" W.C.

PRESSURE DROP ACROSS BAGS
- maximum 4" W.C. after 1 yr. operation

FILTERING EFFICIENCY
- minimum 99.9%

TYPE C

MAXIMUM AIR CLOTH RATIO
- All compartments in operation 4:1
- 1 compartment shut down 5:1
- 2 compartments shut down 6:1

FILTER MATERIAL
- polyester, woven
- 7 oz./sq. yd. weight
- 20 - 30 CFM per sq. ft. permeability ½" W.C.

PRESSURE DROP ACROSS BAGS
- maximum 4" W.C. After 1 yr. operation

FILTERING EFFICIENCY
- minimum 99.9%

FIGURE #5
TYPES OF FILTERS

TABLE #6

TYPICAL FILTER TENDER ANALYSIS

****

	TYPE A - COMPRESSED AIR CLEANED UNITS					TYPE C - SHAKER Baghouse	TYPE B - LOW PRESSURE REVERSE AIR CLEANED
	Top Removable Bags Walk In Plenum			INTERNALLY REMOVED BAGS			
	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 2	COMPANY 4	COMPANY 4	COMPANY 3
Price Less Freight	$ 643,403	$ 826,800	$1,017,723	$ 716,612	$ 781,775	$ 797,259	$ 971,313
Freight	40,175	48,295	3,000	41,859	39,618	12,004	11,200
Price As Bid	683,578	875,095	1,020,723	758,471	821,393	809,263	982,513
Additions to Bid to be Equivalent							
Larger Screws & Rotary Valves	Incl.	15,000	Incl.	15,000	Incl.	Incl.	Incl.
Explosion Vents	Incl.	Incl.	Incl.	Incl.	69,155	Est.45,000	Incl.
Cloth Area Penalty	-	-	21,400	-	37,000	-	26,800
Subtotal	683,578	890,095	1,042,123	773,471	927,548	854,263	1,009,313
Associated Installation Cost:							
Assembly	90,000	95,000	75,000	80,000	65,000	220,000	15,000
Hoisting	30,000	30,000	30,000	30,000	30,000	Incl.	30,000
Electrical	26,400	26,400	26,400	26,400	26,400	31,680	82,080
Extra Ductwork	-	-	-	-	-	160,000	-
Transportation System	160,000	160,000	160,000	160,000	160,000	50,000	160,000
Fire Protection	-	-	-	-	-	93,900	-
Control Devices	10,000	10,000	10,000	10,000	10,000	75,000	10,000
Extra Maint. for Bag Change	-	-	-	25,000	25,000	-	25,000
Compressed Air	180,000	165,000	140,000	165,000	130,000	-	-
Subtotal	1,179,978	1,376,495	1,483,523	1,269,871	1,373,948	1,484,843	1,331,393
Escalation	-	-	-	-	-	-	-
Total Capital Cost	1,179,978	1,376,495	1,483,523	1,269,871	1,373,948	1,484,843	1,331,393
Power Penality	212,500	170,000	127,500	170,000	85,000	0	494,700
TOTAL COMPARABLE COST	$1,392,478	$1,546,495	$1,611,023	$1,439,871	$1,458,948	$1,484,843	$1,826,093
Price as Bid Cost Difference	0	$ 206,517	$ 337,145	$ 74,893	$ 206,970	$ 170,685	$ 298,935
Total Comparable Cost Difference	0	$ 154,039	$ 218,545	$ 47,393	$ 66,470	$ 92,365	$ 433,615

1 - assembly and hoisting to hard to reach areas is expensive and costs will vary considerably depending on the form in which a unit is shipped from the factory

2 - units in the Type C category each have an individual fan which purges the filter cloth. Costs to electrically connect these fans are high compared to Type A and Type B

3 - costs of ductwork are significantly higher when utilizing a large central unit with long duct runs versus locating smaller individual units near the dust sources

4 - cost of dust transportation systems to remove dust from the filter are significant. It is costlier to collect dust from a larger number of individual units than from one central unit.

5 - fires are not uncommon in filters. They are usually confined to one filter and cause it to be out of service for an extended period. Where the complete plant is dependant on a single filter sophisticated fire protection is good insurance. This price is included for the single shaker baghouse only.

6 - Type A filters require a reliable and expensive compressed air system

These factors plus any escalation specified in the tender provide a comparable capital cost. We then assess the operating costs; First there is a significant difference in the power to run the cleaner system. The shaker type unit uses essentially no power, the compressor units with a Type A system consume an average of 240 horse power and the fans used on Type B units consume 560 horse power. We estimate the present value of 15 years energy consumption to be $885 and this is the value used in our analysis. We also analyze units for additional operating costs which includes such items as cost to change filter socks and compressor maintenance cost. The final comparable cost provides a figure on which we base our selection, and unless these are close, say within 5%, the lowest cost units will be chosen.

At #7 we selected a 7 compartment shaker baghouse supplied by Carborundum Environmental Systems. These slides show it partially assembled on site. The unit is particularly well suited to the location because all existing dust control systems terminate in the immediate area and duct runs are short.

Also, the existing building had the structural capacity to carry the load without major modifications, a condition which has proven uncommon in other elevators.

Figure #6 shows a schematic of the filter. There are 25 fan systems feeding 750,000 CFM of air into a common inlet plenum. This plenum feeds any or all of the 7 compartments each of which has 528 bags, 8" diameter x 22' long constructed of 7 oz. polyester. The unit normally operates at an air cloth ratio of 4:1 and will operate satisfactorily at a ratio of 5:1 with one compartment shut down and at a 6:1 ratio with two compartments shut down.

As a precaution against major fire damage there is an isolation wall between each compartment and an open space betwen compartments #3 and #4. During operation there is always complete isolation in the plenum between the two sides of the baghouse. Fan systems #5, #17 and #4 totalling about 100,000 CFM enter the plenum between the two baghouse sections and by means of electrically operated dampers can be diverted to either side. This floater volume allows the air cloth ratio to be equalized on either side of the baghouse.

The filter systems selected at our #14 elevator are shown on this slide. Based on the analysis of tenders we chose continuous high ratio units cleaned by reverse jets of compressed air, as supplied by Ducon Mikropul Limited. These slides show a battery of individual units each serving an individual fan system. There are 14 units with a total volume of 310,000 CFM. Figure #7 shows a typical unit. All have $4\frac{1}{2}$" diameter 10' long filter bags constructed of 16 oz. dacron. One significant feature is the top removeable plenum which allows filter bags to be removed from the clean side of the unit. This full height walk in plenum allows inspection and bag changing while the unit is in operation if necessary.

FIGURE #6

SEVEN COMPARTMENT SHAKER BAGHOUSE - ELEVATOR #7

- SCHEMATIC FLOW -

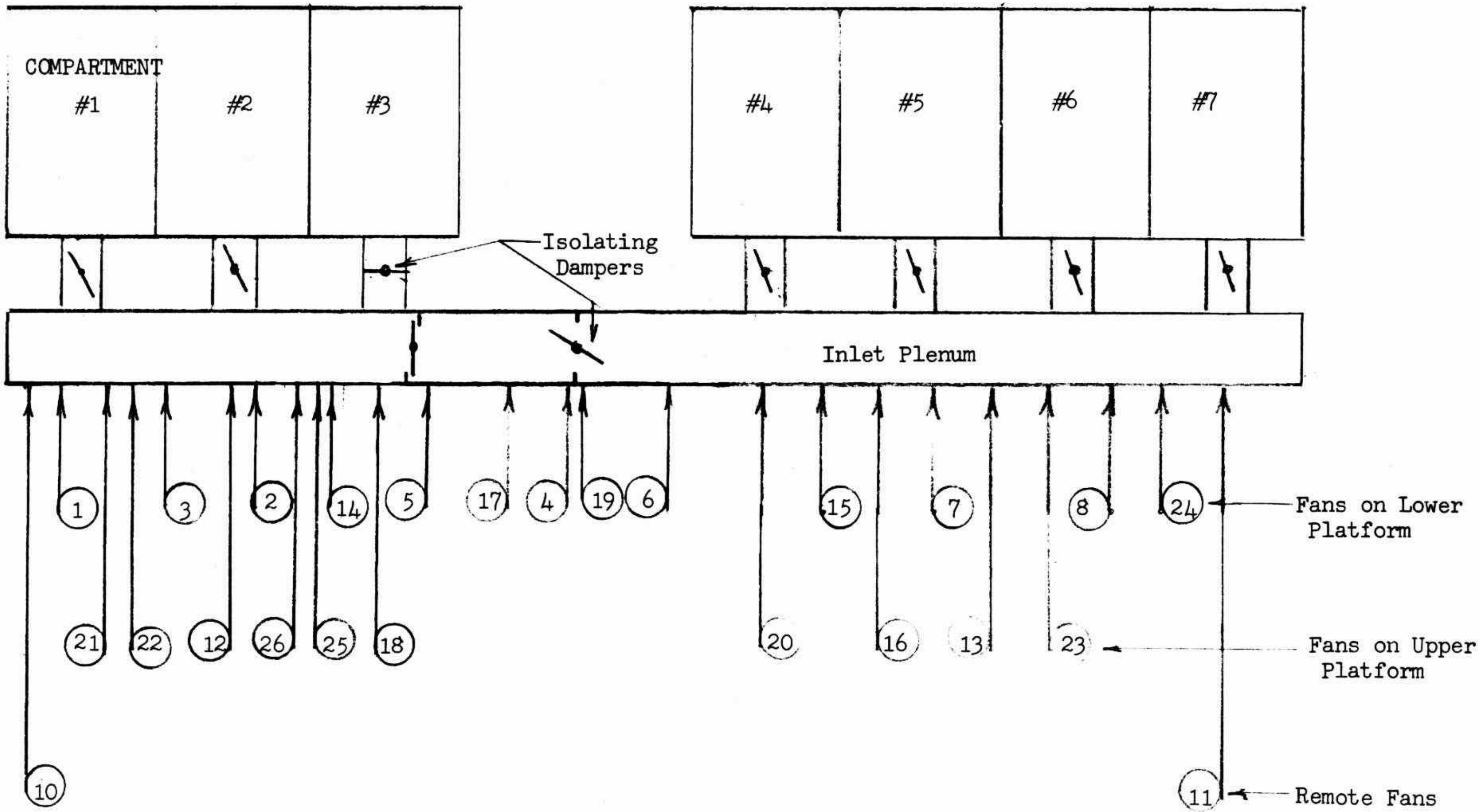
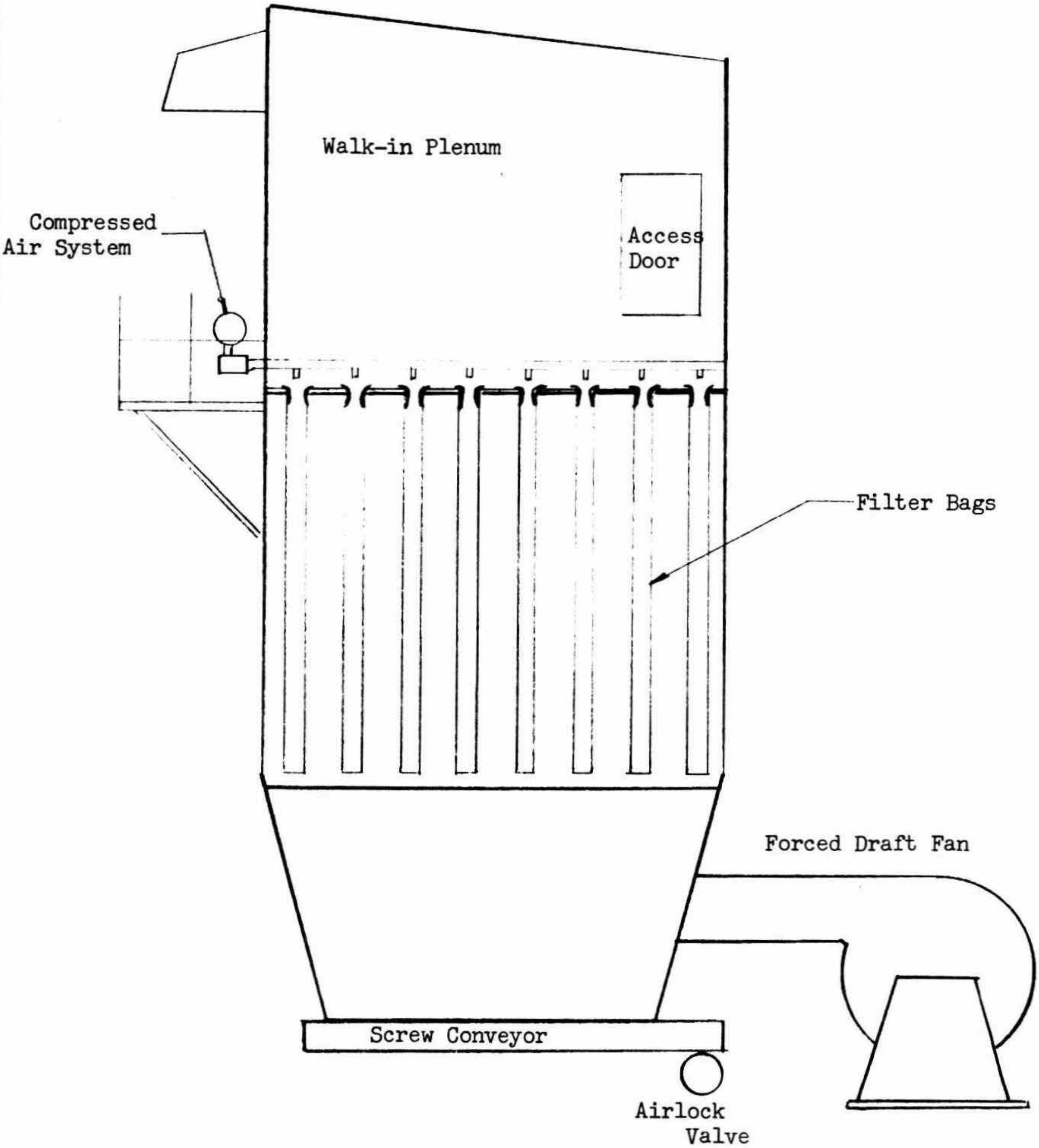


FIGURE #7

ELEVATOR #14

SCHEMATIC OF FILTER

****



From evaluations on seven different installations we found the criteria on figure #8 apply to the filter selection.

FANS The selection of fans is important and requires considerable evaluation. This selection affects not only the direct purchase and installation costs but has an important bearing on power consumption, ductwork costs and filter costs. Figure #9 indicates the various fan systems considered.

System A utilizes an induced draft fan on the clean side of the filter and since the dust does not pass over the fan blades an efficient blade shape can be used; generally a backward curved or in some cases an airfoil shape. The airfoil is susceptible to abrasion damage if dust should leak through the filter and we hesitate to use it in most cases. Another point to consider is that the open fan discharges on this system are noisy and in some locations silencers may be required.

System B utilizes a forced draft fan on the dirty side of the filter. Since dusty air comes into contact with the fan blades a more rugged blade design is used to prevent abrasion and to prevent dust from adhering to the blade. Normally a radial tip blade is used and in some cases of high dust loading or very high pressure requirements straight radial blades are used.

In both systems A and B we limit motor size to 200 horse power, which may necessitate using multiple fans on larger systems. In system C more than one fan is fed into a common filter. This may be required due to fan size limitations, required system flexibility or the economics of a single filter. The fans must be located on the dirty side to achieve proper control and selection is therefore similar to system B except isolation dampers are located on each fan discharge to prevent blowback.

Figure #10 shows a comparison we made of different fans systems for one of our elevators, and also takes into account the effect of using individual filter units or larger units with multiple inlets. It is significant that by incorrect system selection as much as $20,000 or nearly 40% of the best

FIGURE #8

FILTER SELECTION CRITERIA
****

A. Filter Type A - high ratio - cleaned by reversed jet of compressed air

- Satisfactory for all applications but must have a reliable source of clean dry air
- Compressed air costs for smaller systems with total capacity under 200,000 CFM are relatively high
- Economical to use separate units located near dust loads where loads are at diverse points

****

B. Filter Type B - high ratio - cleaned by reverse flow of low pressure air

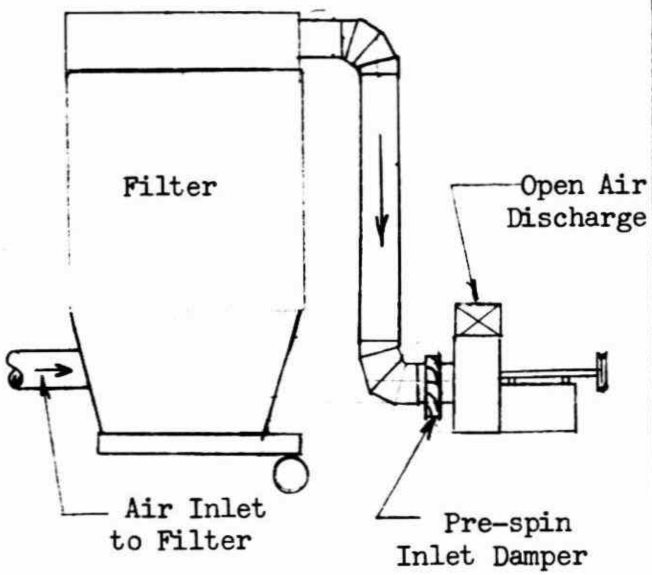
- Cost for electrical connection high and power consumption is high. On installations with less than 200,000 CFM this may be offset by the compressed air costs on Type A units.
- Economical to use separate units located near dust loads where loads at are diverse points

****

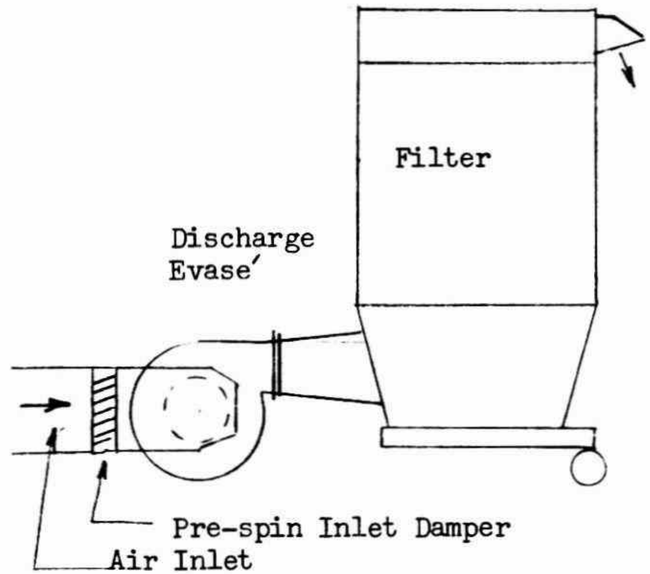
C. Filter Type C - shaker type units

- Economical on systems with over 400,000 CFM
- Lowest power consumption
- Ductwork is costly if air must be gathered from distant points
- Requires large space and substantial foundations

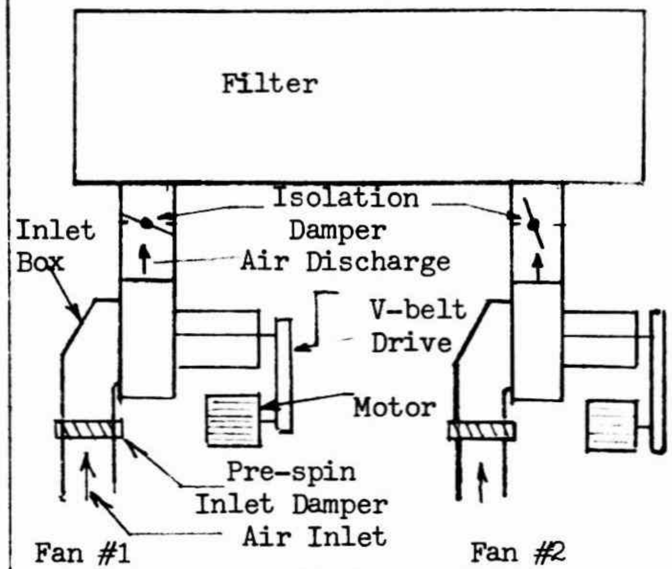
****



TYPE A - INDUCED DRAFT



TYPE B - FORCED DRAFT



TYPE C - MULTIPLE FORCED DRAFT

ADVANTAGES

- high efficiency (maximum 80%)
- lowest purchase price
- lowest maintenance cost

DISADVANTAGES

- high noise level at discharge and may require silencer which consumes power
- higher duct cost
- inflexible

ADVANTAGES

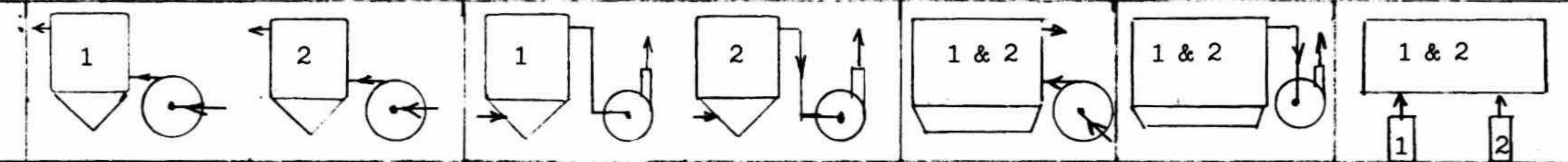
- More flexible as total h.p. not limited and individual fans can be shut off

DISADVANTAGES

- less efficient (Maximum 68%)
- larger (slow speed) units

FIGURE #9 FAN COMPARISON
****

FIGURE #10 - ALTERNATE FAN AND FILTER SYSTEMS FOR SYSTEM #1 - 12000 CFM AND SYSTEM #2 - 18000 CFM

ALTERNATE	A		B		C	D	E
ITEM / COST							
Filter Cost	$ 15,590	$ 20,130	$ 15,590	$ 20,130	$ 28,200	$ 28,200	$ 28,200
Filter Install.	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Fan Cost	3,190	3,790	2,120	2,360	4,390	3,220	6,920
Motor Cost	1,450	2,330	1,450	2,330	3,710	3,710	3,780
Fan and Motor Installation	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Structural	3,800	3,800	3,800	3,800	3,610	3,610	3,610
Additional Duct	0	0	1,850	2,220	(-500)	2,960	0
Fan Volume Control	3,500	3,500	3,500	3,500	3,500	3,500	7,000
Silencer	0	0	680	680	0	910	0
Comparable Capital Cost	31,030	37,050	32,490	38,520	48,410	51,616	56,010
HP Penalty @ $885	68,080 3,628		71,010 531		3,894	0	3,894
Total Comparable Cost	$ 71,708		$71,541		$52,304	$51,610	$59,904
BHP @ 70°F (Horsepower)	35.4	53.1	33.6	51.1	88.5	84.1	88.5

price could have been wasted.

Most of our fans are equipped with automatically controlled pre-spin inlet dampers. These have two functions, firstly to automatically adjust the fan volume to compensate for changes in filter back-pressure or in air demand, and secondly by using a prespin type damper a considerable power saving is achieved over a throttling damper. This concept is a significant change in our design philosophy in response to increases in power costs and the need for more accurate control.

The selection of filters and fans are the major decisions to be made before the equipment arrangement can be finalized and drawings and specifications produced for construction. During the design process we also select equipment and design several major auxiliary systems.

COMPRESSED AIR SYSTEM

A reliable compressed air system is crucial to the satisfactory operations of the filters using this mode of cleaning. The schematic on Figure #11 shows the compressed air flow at elevator #14. We required an average of 435 CFM to run the filters and installed 2 - 425 cfm rotary screw compressors in order to have a 100% standby capacity. The system includes a 900 CFM regenerative dryer and compressed air filtering system. All compressed air equipment is housed in a building with a temperature controlled environment, and which provides a filtered air supply for the aftercoolers and compressed air intake.

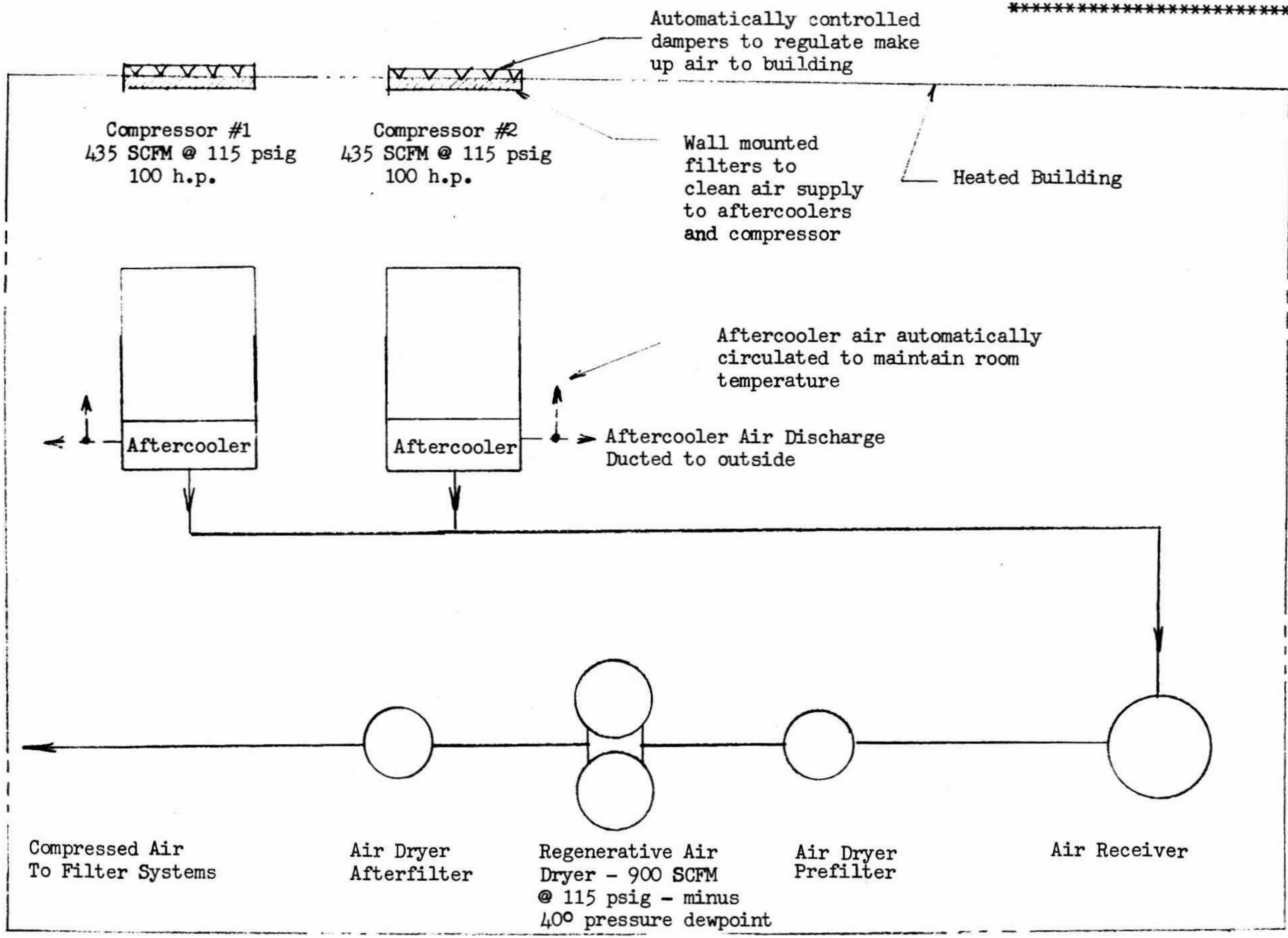
POWER SUPPLY

We also had major additions to make to our power supply systems at all elevators. The new dust control systems add about 12,000 KW demand which will double our total electrical loads. This has required adding three complete substation complexes plus upgrading a fourth.

SYSTEM CONTROL

The filter systems will all be controlled from central panels located

FIGURE #11 COMPRESSED AIR SCHEMATIC ELEVATOR #14



in the elevator control centers. This slide shows a panel at elevator #14. Central control is important to eliminate delays in starting, provide continuous status indication and to insure that maximum advantages is taken of every opportunity to shut off systems and conserve power.

DUST HANDLING

Another integral part of the system is the dust handling and disposal system. All dust is eventually manufactured into pellets at pelleting facilities located at our #7 and #15 elevators. From the fitering system the dust is conveyed either mechanically or pneumatically to storage bins. At elevator #7 and #14 this dust is fed into a large pneumatic system and conveyed at a rate of 5 tons per hour to the pelleting plant 1200 ft. away. At elevators #4 and #6 dust is mixed with refuse screenings and hauled in specially designed trucks to the pellet plants.

V COSTS

Table #7 gives a summary of costs as we expect them to be upon completion of the program. Other than their sheer magnitude, it is important to note how high costs are for items in the auxiliary categories other than for major equipment and not taking these into proper account at the beginning of a program can be a major planning mistake.

VI RESULTS

The major results of our program can be summarized as follows:

1. There will be a major improvement in working conditions within the terminal.
2. There will be a reduction of more than 90% in the amount of dust discharged. There will be corresponding increases in air quality in adjacent areas of the city.
3. Saskatchewan Wheat Pool will have spent $17 million on dust control and an additional $1.5 million on demolition.
4. Power requirements at our elevators will increase by 12,000 KW which will double our present load.

TABLE #7

COST SUMMARY OF DUST CONTROL PROGRAM
FOR
ALL SASKATCHEWAN WHEAT POOL THUNDER BAY ELEVATORS
****

(1)	DUST COLLECTOR AREA		
	1.1 Filters, Supply and Installation	$ 3,178,000	
	1.2 Fans, Supply and Installation	1,046,000	
	1.3 Motors, Supply and Installation	404,000	
	1.4 Structural Supports	877,000	
	1.5 Compressed Air Systems	695,000	
	1.6 Dust Handling Systems	560,000	
	1.7 Ductwork	2,385,000	
	1.8 Substation, Supply and Construction	1,039,000	
	1.9 Electrical Supply and Installation	1,447.000	
			$11,631,000
(2)	IN HOUSE DUST CONTROL IMPROVEMENTS		$ 3,014,000
(3)	ENGINEERING		$ 1,515,000
(4)	MISCELLANEOUS		$ 610,000
(5)	POLLUTION ABATEMENT INCENTIVE ACT GRANT		$ (-466,000)
(6)	SCALE AND GARNER VENT DUST CONTROL SYSTEMS		$ 524,000
(7)	DEMOLITION OF OLDER ELEVATORS		$ 1,500,000
			$18,328,000

****

DISCHARGE OF HEAVY METALS TO MUNICIPAL SEWERS

"THE CRUNCH MAY COME"

Sludge from municipal sewage treatment plants has historically been disposed of by the least expensive method available. For the majority of municipalities in Ontario, this has been by spreading of sludge on land, frequently with little regard for the environment. With the increasing emphasis on recycle, reuse and reclamation, and the increasing cost of commercial fertilizers, there is a growing tendency towards utilization of sludge on agricultural lands rather than disposal, and in an environmentally acceptable manner. Should the heavy metal content of the sludge be too high in the future, however, municipalities will have to find an alternate and perhaps more costly and less socially accaptable method of disposal. Since unusually high levels of metals in municipal sewage can generally be traced to an industrial source, industries may well be forced to reduce the levels of metals discharged to municipal sewers. This may be accomplished through improved housekeeping, by better use and reuse of raw materials and waste products, or by pretreatment of industrial effluents for metal reduction prior to discharge.

by

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Mr. Black received his B.Sc. from the Ontario Agricultural College, Guelph, & his BA Sc in Mechanical Engineering from the University of Waterloo in 1965. He worked in the Research Division of the Ontario Water Resources Commission, as Project Engineer and Supervisor from 1964 until 1973. In 1974 he was appointed Supervisor of the Wastewater Treatment Section in the reorganized Ministry of the Environment. This Section conducts research work on new or improved methods of wastewater treatment and provides a technical advisory service to the Ministry, municipalities, industry and the public.

DISCHARGE OF HEAVY METALS TO MUNICIPAL SEWERS

"THE CRUNCH MAY COME"

By:

S.A. Black

Municipal wastewaters contain a wide variety of heavy metals at varying concentrations. Although high levels of any one or more heavy metals in a wastewater generally indicates industrial inputs, domestic sewage itself contains significant amounts of several metals. Metal contaminants may be picked up from water pipes, tanks, various toilet preparations, food washings, etc., and from human excreta itself. For example, an adult will normally excrete everyday about 1 mg iron, 2 to 3 mg copper, 0.2 to 2 mg nickel, 10 to 15 mg zinc and 1 to 2 mg arsenic.

Even though the amounts of a metal in the sewage may seem small and perhaps insignificant, sewage treatment processes tend to concentrate the metals in the sludge. A normal domestic sewage may contain about 0.5 mg/l zinc and 0.1 mg/l copper. After digestion, however, the sludge may well contain up to 2000 mg zinc/kg dry solids and 300 mg copper/kg dry solids. Domestic sewage sludge will, therefore, invariably contain significant quantities of heavy metals while most municipal wastewaters contain industrial discharges to further augment the heavy metal content of the sludge.

If sewage sludges are applied to agricultural lands, contamination of the soils by heavy metals may result, adversely affecting the quality and quantity of the crop produced.

This paper discusses the implication of heavy metals contained in municipal wastewaters in relation to the treatment process, the sludge produced and the utilization and disposal of that sludge. The paper then discusses alternate means of reducing the heavy metal content of the sludge and the implications these means may have on industries.

Heavy Metal Concentrations in Municipal Wastewaters

Heavy metals in sewage treatment systems are of concern not only because their discharge into watercourses is detrimental to the environment (1), but also because they can reduce the efficiency of aerobic sewage treatment and anaerobic digestion of sewage sludges (2,3, 4,5) and affect the ultimate disposal of the sludge.

Metal concentrations in raw sewage are generally much higher at sewage treatment plants receiving industrial wastes than at plants receiving purely domestic sewage. Although there is a general increase in levels of most metals with industrial input, dramatic increases in specific metals are invariably traceable to specific industrial inputs.

Oliver and Cosgrove (6,7*) reported on the concentrations of heavy metals in the raw sewage feed to 10 municipal sewage treatment plants in Ontario. Table I summarizes the findings. In general, the metal concentrations were much higher at plants receiving industrial wastes (i.e. Oakville) than at plants receiving only domestic sewage (i.e. Burlington's Elizabeth Gardens Plant).

Heavy metals enter the wastewater stream in both the dissolved state and in the insoluble form. It is primarily the soluble metal ion that causes interference with the biological processes in the sewage treatment plant, but fortunately, by the time the sewage reaches the plant, most of the metals are present in insoluble forms.

The interactions between the heavy metals and municipal sewage dictate the form in which individual metals enter the plant. At the normally neutral pH range of sewage, dissolved metals tend to be precipitated in the sewer by interaction with the sewage primarily through the formation of hydroxides. Since it is mainly the soluble metal ion which causes interference

* This paper has drawn heavily upon these works of Oliver and Cosgrove since they are based upon studies at Ontario plants. Similar data and relationships have, however, been reported by others (8,9,10).

TABLE I

CONCENTRATIONS OF VARIOUS HEAVY METALS FROM 10 ONTARIO MUNICIPALITIES

Municipality (Plant)	Cd	Cr	Cu	Ni	Pb	Zn
Oakville	0.006	0.29	0.31	0.33	0.23	2.40
Clarkson	0.02	0.14	0.26	0.08	0.37	0.34
Oshawa	0.008	0.29	0.09	0.80	0.31	1.13
Aurora	0.01	1.39	0.06	0.10	0.19	0.19
Woodstock	0.04	0.09	0.35	0.10	1.1	1.01
Ingersoll	<0.01	0.07	0.15	0.06	<0.05	0.34
London (Vauxhall)	0.02	1.4	1.20	1.8	0.05	0.8
Dundas	<0.01	0.02	0.11	0.06	<0.05	0.14
Burlington (Elizabeth Gardens)	<0.01	0.04	0.10	0.04	<0.05	0.11
Burlington (Skyway)	<0.01	0.26	0.30	0.03	0.15	0.74

Note: All units in mg/l

with biological processes, any precipitation of the metal which occurs will correspondingly reduce the severity of interference and process inhibition. The fact that high concentrations of Cu, Ni, Zn and Cr as well as frequently other metals are invariably found in sewage sludges makes it evident that precipitation occurs at some stage within the purification process. In the conventional activated sludge process, precipitation and settling out of a varying portion of the metals occurs within the primary clarifier. A portion of the metals escaping through the primary clarifier is removed within the waste activated sludge of the secondary process. This is probably related to a number of factors including precipitation by, and adsorption onto, the biological floc.

Oliver and Cosgrove (7) determined the percentage removal of various heavy metals within the primary and secondary stages of the conventional activated sludge process. Table 2 presents a summary of their results indicating a rather variable removal for different metals. The higher percentage of removal generally occurred within the primary clarifier. In the overall process, 93% of the lead was removed while only 16% of the nickel was removed.

It would appear that removal of a particular heavy metal within the primary clarifier is highly dependent upon the form in which it enters the plant.

Table 3 presents a summary of Oliver and Cosgrove's (7) data on the phase distribution of metals in raw sewage. Here it may be noted that 67% of the nickel entering the plant studied was in the soluble form, whereas only 5.2% of the lead was soluble. This relationship undoubtedly plays an important role in the different primary clarifier percentage removals seen in Table 2.

TABLE 2

THE METAL REMOVAL EFFICIENCY OF A CONVENTIONAL

ACTIVATED SLUDGE TREATMENT PLANT

Metal	Percentage Removal		
	by Primary	by Secondary	by Overall Process
Cadmium	60	50	80
Chromium	55	54	79
Copper	33	60	73
Lead	66	79	93
Nickel	15	1	16
Zinc	54	50	77

TABLE 3

DISTRIBUTION OF HEAVY METALS IN RAW SEWAGE

Metal	Total Range mg/l	Average Percent Distribution Soluble	Insoluble
Cadmium	0.006-0.04	17	83
Chromium	0.02 -1.4	6.8	93.2
Copper	0.06 -1.2	38	62
Lead	$<$0.05 -1.1	5.2	94.8
Nickel	$<$0.03 -1.8	67	33
Zinc	0.11 -2.4	24	76

The removal of dissolved metals in municipal treatment systems can be considerably enhanced by additional chemical treatment. Several investigators have investigated the effect of chemical precipitants on the removal of metals from sewage (11,12,13,14,15,16). The treatment that is being applied to the majority of municipal treatment plants in Ontario for phosphorus removal represents this type of additional chemical treatment, thereby precipitating out higher concentrations of heavy metals. This reduces the metal discharge in the plant effluent but compounds the problems caused by the concentrations of metals in the sludge.

Experience to date in Ontario (MOE Project Operations Records) is that chemical addition for phosphorus removal does enhance the removal of heavy metals in municipal sewage treatment plants but this is reflected in increased levels of metals in the sludges of such systems. In Ontario, the predominant prime coagulants used for phosphorus removal are aluminum and iron. Much of the iron used is in the form of ferric or ferrous sulphate or chloride from reclaimed waste pickle liquor. When considering the impact of these chemicals on heavy metal removal, one must not overlook the potential heavy metal content of these materials. Table 4 presents a list of the heavy metal content of some of the phosphorus removal materials available in Ontario. Some of these can add considerably to the heavy metal content of the sludge.

Generally, the concern over heavy metal discharges to municipal sewers has been related to the effects of those heavy metals on the sewage treatment plant processes and the implications of metal discharges in the effluent. In this respect, the model sewer use bylaw prepared jointly by the Ministry of the Environment and the Municipal Engineers Association (17),

TABLE 4

HEAVY METAL CONTENT OF COMMERCIALLY AVAILABLE

PHOSPHORUS REMOVAL CHEMICALS

Chemical (Supplier)	Cd	Cr	Cu	Ni	Pb	Zn
$FeCl_3$						
(A)	<80	80	15	40	275	400
(B)	20	180	160	50	2100	14,500
(C)	1.4	661	12	42	113	260
$FeCl_2$						
(A)	<0.1	36	5.6	7	<0.1	1.7
(B)	<1	20	9	19	1.5	2.3
$FeSO_4$						
(A)	<0.1	3.3	0.5	6.5	<0.1	5.6
(B)	0.2	51	240	29	4.6	860
Alum						
(A)	0	<1	1.0	<1	0.5	<1
(B)	0.68	47	0.75	1.2	0.8	2.2
(C)	0.15	0.2	1.0	0.06	1.0	2.5
Lime						
(A)	0.2	0.6	3	3	1	25

limits the discharge to the municipal sewer of most metals to 5 mg/l, "since this is considered to be the minimum practical level to require industry to meet on a continuous basis". These limits following initial dilution with the sewage, are also generally below the levels considered to be toxic to sewage treatment biological processes.

Consideration must now also be made of the effect of these heavy metal discharges on the composition of the sewage sludge and how this relates to their disposal.

Sludge Disposal in Ontario

With a population of some 8 million people, Ontario has a total of some 360 sewage treatment plants of which 230 are mechanical, primary and secondary plants, the remainder being lagoons. Of the mechanical plants, 71% provide for secondary treatment. A total of some 860 million gallons of sewage is processed everyday.

If one assumes that sludge production from sewage treatment is equivalent to 0.5% of the total flow, then approximately 4.3 million gallons of sludge ranging from 2 to 9% solids are produced per day in Ontario and must be suitably disposed of.

Present sludge disposal practices in Ontario include incineration, disposal onto farmers' fields, lagooning, dumping into sanitary landfills and dewatering and stockpiling for home garden usage. Metro Toronto, Hamilton and London each have incinerators and between them incinerate approximately 41% of the sludge produced in Ontario. Of the remainder, about 70% is disposed of onto farmers' fields, 20% into sanitary landfills and 10% by other means.

Because of their relatively small scale, for the majority of the sewage treatment plants in Ontario, land application has proven to be the most satisfactory solution to the sludge disposal problem.

Keeping in step with the overall concept of reuse, recycling and waste reclamation, the Ontario Ministry of the Environment is now recommending that wherever possible, sludge be utilized on agricultural lands for its soil amendment and fertilizing properties.

To this end, this Ministry is working with other governmental agencies through an Interministerial Committee to prepare guidelines and regulations covering the land application of sludge so that the practice may be continued such that maximum benefit from the sludge may be realized with minimum adverse effect on the environment. One of the major concerns in the development of these guidelines and regulations is the possible long-term effects of heavy metals applied to soils in sewage sludge.

Heavy metals in Relation to Land Utilization of Sewage Sludge

Although many of the heavy metals contained in sewage sludges are considered to be essential for plant growth and animal nutrition, there is often a narrow margin of concentration between when an element is a nutrient and when it becomes a toxicant. It is recognized that metals such as copper, molybdenum and zinc are required by plants and animals, and cobalt and selenium are essential for animal nutrition. Copper, cadmium, nickel and zinc have caused toxicities in plants. Cadmium, chromium, mercury, molybdenum and nickel have been found toxic to animals (18). To make things more complicated, the levels in soils at which toxicities occur will vary from soil to soil and have not as yet been accurately established; the amount of

metals taken up by plants will vary from specie to specie; climate during the growing season will affect the uptake of metals by any given plant specie.

Metals applied in sewage sludge have caused phytotoxicity at several sites in the United Kingdom (19), in Germany (20,21) and in France (20). Various authors have reported toxic effects of specific metals contained in sewage sludge in field and greenhouse studies.

Metals leach very slowly from soils, and field crops have been shown to remove less than 0.3 pounds per acre per year of any of the toxic metals. Once metals are in the soil, there is little hope of getting them out. Thus, the logical approach is to ensure that metal levels in soils are never allowed to build up to hazardous concentrations. Such is the course of action taken in the preparation of the guidelines.

Sewage sludges with high metal content are unsuitable for use in agriculture, while those with low metal content are an excellent source of plant nutrients. Since sewage sludge application rates are based on plant available nitrogen, acceptable metal concentrations should also be related to nitrogen. Thus, acceptability of sewage sludges for use in agriculture are being based on the ratio of ammonium nitrogen to metal concentrations in the sewage sludge. Metals currently considered in the guidelines are: Arsenic, Cadmium, Cobalt, Chromium, Copper, Mercury, Molybdenum, Nickel, Lead, Selenium and Zinc.

If a sewage sludge containing too high a concentration of one or more metals is to be used on agricultural lands, some means of reducing that metal concentration must be effected. If metal concentrations of the sludge cannot be reduced, an alternate means of disposal must be found.

Options Available for Sludge Disposal

If a particular sewage sludge is unsuitable for utilization on agricultural lands, there are several options available to the municipality for its ultimate disposal. These options involve either finding an alternate means of disposal or making the sludge acceptable for land application.

Alternate Means of Disposal

Sanitary Landfill: Disposal of sewage sludge into a sanitary landfill is perhaps the most attractive alternate to a municipality for the disposal of sludge. Almost every municipality within the province has a landfill site used for the disposal of garbage and refuse and one might well assume that it would be suitable for sludge.

Such is not always the case. All sanitary landfills have the potential of contaminating groundwater and many of contaminating surface waters. Stabilized sludge for landfill disposal should be sufficiently dewatered to minimize the quantity of free water present. A sanitary landfill must be managed so that wastes are systematically deposited and covered with earth to control environmental impacts within defined limits. This distinguishes a sanitary landfill from an uncontrolled dumping operation. Leachate and runoff from a sanitary landfill should be minimized, and when necessary, collected and suitably treated to prevent pollution of ground and surface waters.

Incineration: Incineration of sludges is another alternative to sludge application to farmland but for economic reasons, it is suitable for only the larger urbanized areas with populations of 200,000 people or

more. Although incineration results in a highly concentrated ash which must be suitably disposed of, it is a relatively small proportion of the material handled and is generally suitable for landfill disposal. Although there has been concern over air emissions from incineration of sewage sludges, recent studies by this Ministry and the Environmental Protection Service (in press) have shown that little metal and negligible phosphorus is lost from the system through air emission as long as adequate scrubbing is provided.

Municipally Owned Sludge Disposal Site: Another alternative available to the municipality involves the purchase of land to be used purely as a disposal site for sludge. Such is the practice adopted by Chicago, Illinois and Denver, Colorado. In both cases, the municipalities have purchased land which is used basically for sludge disposal. In the case of Chicago, the sludge is barged some 120 miles and then piped an additional 30 to 40 miles to old surface strip mine areas. Sludge is applied by various means to reclaimed land where corn is grown. Although in both cases some soil and crop analyses are performed, there is no way to predict what would happen if the land at some future point in time were to be used for growing other crops such as soybeans or tomatoes which are considerably more susceptible to high soil metal levels than is corn. Thus, the land is virtually committed to sludge disposal.

In Ontario, where there is considerable concern over preserving our agricultural lands, this does not seem to be an acceptable alternative. In addition, the municipality places itself into direct competition with local farmers which can only result in social problems.

Heavy Metal Reduction in Sewage Sludge

There are two obvious alternatives for reducing the heavy metal content of sewage sludge; one being the precipitation and recovery of the metals from the sewage or sludge, the other being the reduction in the amount of heavy metals discharged to the sewer.

Metal Removal from Sludge - Several recent attempts have been made at recovering the heavy metals from sewage sludges (22,23,24,25). Oliver and Carey (23) demonstrated that Cadmium, Copper, Nickel and Zinc solubilized from wet sludge with H_2SO_4 or HCl could be electroplated using fluidized bed electrodes. As the cost of the acid alone would be more than double current sludge disposal costs, however, it was concluded that little benefit would be attained from the recovery of trace metals from sludge because of high processing costs.

Scott and Harling (24) investigated the extraction and recovery of phosphorus and iron, together with a few other metals from the sludge and filter cake of the North Toronto Sewage Treatment Plant. The removal of metals was effected by digestion with sulfuric acid and a cursory study of the recovery of iron and phosphorus from the acid leachate performed. Costs of the procedure were in the order of $30 to $35 per million gallons of sewage influent and thus it was also considered impractical at this time.

Metal Reduction at Source - The other alternative for reducing the metal content of sludge involves reducing the metal input to the sewer at its source. This is the alternative which will have direct impact upon the local industries, but which would appear to be the most logical and acceptable alternative to the municipality.

As mentioned earlier, high concentrations of heavy metals in municipal sewage can generally be traced back to one or more industrial source. In the case of a small municipality with one or two major industries, it is generally not a problem to identify the source of metal contamination. Oliver and Cosgrove (7) for instance determined that the high concentrations of Chromium in the Aurora sewage came from the local Tannery, while the high concentrations of Zinc in Oakville sewage were attributable to a radiator manufacturing operation. Taking the other extreme of a large municipality with a high diversified industrial community, the sources of industrial metal contamination may not be so well defined. Klein et al (10) determined that the percentage contribution of heavy metals to the wastewater in New York City from electroplating and photoengraving is minor, except for Nickel. The major metal loadings seem to come from the other industries, domestic sewage and stormwater. Table 5 presents some of the data from the New York City study. As can be seen, the Electroplating and Photoengraving industries contributed less than 20% of the sewer loadings of Cu, Cr, Zn and Cd in each case, less than the residential contribution. The major contribution of these metals was attributed to other industries, urban stormwater and unknown sources.

From the above, one could assume that in a major metropolitan area such as Metro Toronto, it would be quite difficult to make a major reduction in all metals entering the sewerage system, because of the diverse sources. In most other municipalities, however, metal sources are generally more easily defined and controllable.

TABLE 5

HEAVY METAL LOADINGS IN NEW YORK CITY WASTEWATER

Metal	Total Loading (lb/day)	Electroplating and Photoengraving (lb/day)	Percent of Total	Estimate of Residential Contribution (lb/day)	Percent of Total	Other* Sources (lb/day)	Percent of Total
Cu	3,820	611	15	1440	38	1770	46
Cr	2,340	345	14	640	27	1350	58
Ni	1,870	1010	53	640	34	220	12
Zn	10,440	830	7	1680	16	7930	76
Cd	341	65	19	128	38	148	43

* Other Sources include other industries and urban stormwater

The City of Windsor (personal communication) presents a good example of what can be achieved in a relatively industrialized municipality in Ontario through source control of heavy metal discharges. In 1974, the City amended its sewer use bylaw to bring it up to the standards of the model sewer use bylaw and provided appropriate and necessary enforcement. Table 6 presents loading values of various metals from the electroplating industries prior to and following the enactment and also recent total sewage loadings.

As seen in this table, the metal loadings from the electroplating industries were reduced drastically through the enforcement of a not overly restrictive bylaw. Whereas this sludge would not have come near meeting the sewage sludge application guidelines in 1969, the raw sewage metal levels are now down to a level where land application would be acceptable. Unfortunately, the chemical now being used for phosphorus removal contributes more of the heavy metals to the sludge than do the electroplating industries and in addition the sludge is not digested, in conflict with the guidelines.

It is reported that this reduction in metals was effected at little expense to the industries, but was accomplished through better housekeeping, minor process changes and elimination of the cyanide process. In some instances, the industries have financially profited from the bylaw through higher recovery of raw materials.

In the later 1960's and early 1970's, the Waterloo sewage treatment plant was being frequently upset by high concentrations of metals in the raw sewage. Therefore, they too revised their sewer use bylaw in 1973 to come into line with the model bylaw and stricter enforcement was carried

TABLE 6

METAL LOADINGS TO THE WINDSOR SEWER SYSTEM

FROM ELECTROPLATING INDUSTRIES

Metal	Loading to Sewer		Total Load at Plant
	1969	1976	1976
Copper	11	5	8
Chromium	150	8	8.5
Cyanide (HCn)	26	negligible	negligible
Nickel	41	8	12
Zinc	50	7	16

Note: All units in lbs/day

out. Table 7 outlines the effect of the bylaw on the metal concentrations of the raw sewage and digested sewage sludge of the Waterloo sewage treatment plant. As of 1974, the Waterloo sludge now meets all of the criteria for land utilization and is therefore acceptable for land application under the proposed guidelines.

Conclusions

In conclusion then, yes the crunch may well come when industries are forced to meet stricter requirements before being permitted to discharge their wastes containing heavy metals into municipal sewer systems. Such a requirement, however, need not necessarily be looked upon with dread. The examples of Windsor and Waterloo show that reductions in heavy metal discharges may be accomplished at no great industrial expense.

Industrial processes generally have about a 20 year life, at which time equipment and process changes are required to remain technically and economically competitive. This is the time when the industry should take an extremely critical look at its equipment, processes and materials and waste handling. Any reduction of metals discharge in the plant effluent will mean a savings in raw materials which cannot help but result in a savings in material costs.

True, there are instances when economic recovery of metals from waste streams is not possible. Reduction in metals from these discharge streams will necessarily require a net expenditure by the industry. However, if it means the difference between a land application cost of $30 per ton and a sanitary landfill cost of $40 per ton sewage sludge dried solids, the municipality will have no alternative than to strictly enforce its bylaws.

TABLE 7

METAL CONCENTRATIONS IN RAW SEWAGE AND DIGESTED SLUDGE

AT THE WATERLOO SEWAGE TREATMENT PLANT

Metal	Raw Sewage		Digested Sludge	
	1970	1974	1970	1974
Cadmium	0.05	0.02	1.1	0.8
Chromium	0.49	0.17	51	41
Copper	0.50	0.30	36	27
Lead	0.28	0.07	9	10
Nickel	0.16	0.12	4.5	4.4
Zinc	0.43	0.30	51	28

Note: All units in mg/l

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SOLID LIQUID SEPARATION UTILIZING AN INCLINED PLATE SEPARATOR AND FILTER PRESS

Industrial waste treatment frequently involves removing suspended solids from an effluent stream, resulting in a clear supernatant and a dewatered dry sludge cake. One effective treatment process to accomplish this, the inclined plate clarifier, has found wide acceptance in Europe and is gaining acceptance in North America. The principle of operation is reviewed and some operating experiences in Ontario are described. The inclined plate clarifier offers space savings of up to 90 per cent, compared to conventional clarifiers.

Conventional clarifier sludge underflow concentrations are usually in the range of one to 12 per cent. These voluminous quantities can be dewatered to 30 to 50 per cent solids by using automatic filter presses while producing a high degree of filtrate clarity. The combination of inclined plate clarifier and automatic filter press provides a cost effective approach to suspended solids removal and concentrations.

by

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LIQUID-SOLIDS SEPARATION UTILIZING AN INCLINED PLATE SEPARATOR AND A FILTER PRESS

by Roy Verstraete, P.Eng.

INTRODUCTION.

The separation of solids from liquids is an area that has attracted many different approaches. One involves a combination of two unit operations, namely clarification and sludge dewatering.

In clarification the suspended solids are separated from the waste stream and a clear supernatant is discharged. The suspended solids are then in a low concentration sludge of 1-5% solids. To accomplish clarification an inclined plate clarifier has been used.

The second unit operation is sludge dewatering using a recessed plate filter press. In this process the solids from the sludge are retained within the filter media to form a low volume dry cake of 30-60% solids while again producing a clear filtrate.

Inclined Plate Clarification.

History.

The inclined plate clarifier dates back to the late fifties and early nineteen sixties. In the fifties, patents were awarded to the National Research Council of Canada. In the sixties this technology was brought into actual installations by Pielkenrood (developed by Royal Dutch Shell) in the Netherlands with their corrugated plate separator. Also Axel Johnson and Granges Engineering, both of Sweden, installed their inclined plate clarifiers, initiating a trend away from conventional clarifiers. In 1975 our group, joined with a Canadian inventor of an inclined plate clarifier, a product of his private research.

Theory.

In conventional clarifiers the settling capacity is primarily a function of surface area rather than depth. In these clarifiers, surface area is the same as settling area. This is the key point. To increase the settling area in a given spatial surface area, one could stack plates horizontally to achieve a settling area equal to the surface area times the number of plates. But sludge removal would be very difficult. Setting the plates on a 45-55 degree incline makes sludge removal possible. See Fig. 1. The effective settling area of each plate is equal to its horizontal projection. As the plates are packed relatively closely, 2" to 6" apart, their projections overlap. To determine the total settling area, the horizontal projections are added together. This theoretical total settling area is up to 10 times the settling area per surface area compared to a conventional clarifier. Each plate is typically 3-4 ft. wide and 8-9 ft. long.

Now let's look at what happens to suspended solids as they travel thru the inclined plates. See Fig. 2. The influent is fed from the side of each plate along the feed slot across and up the plate.

Looking at an individual suspended solid, we note that it has two

major force vectors acting on it in this counter current system. One is the gravity force pulling the particle down. The second is the velocity vector pushing the particle up along the length of the plate. The resultant force on each solid particle directs it to the plate. The particle impinges on the plate and meets with other particles that are sliding down the plate toward the sludge hopper. Laminar flow is maintained in the flow up between the plates promoting orderly settling and sliding down into the hopper.

In studying clarification the usual starting point is the assumption that settling in a free container conforms to Stokes Law. Stokes developed the equation for drag force exerted on a falling particle in laminar flow conditions. Newton's Law equates effective particle weight to drag forces to yield the terminal velocity of the particle. This also applies to inclined plate separation theory.

Further, Hazen's theory of surface loading is applicable to the inclined plate counter current flow system. Refer to Fig. 3. The velocity of the stream is -

$$V = \frac{q}{d.w.\ \sin\alpha}$$

V - average linear velocity
q - volumetric flow rate
d - horizontal distance between plates
α - angle of elevation to the horizontal
w - width of plates

The average linear velocity has two components namely

V_y the vertical component and V_x the horizontal component.

$$V_y = V.\ \sin\alpha = \frac{q}{d.w.}$$

$$V_x = V.\ \cos\alpha = \frac{q.\ \cos\alpha}{d.w\ .\ \sin\alpha}$$

The upward vertical velocity component V_y is opposed by the downward

vertical settling velocity V_s. The residual vertical velocity of the particle is then the upward vertical velocity V_y less the vertical downward settling velocity V_s.

Now, looking at the worst case of a suspended solid particle entering at point A it must reach point B before the stream exits from the plate cell. Hence the horizontal settling time must be less than or equal to vertical settling time for the particle.

Horizontal settling time $\leqslant$ vertical settling time
Developing and simplifying the algebraic equation

$$\frac{q}{W.L} \leqslant V_s \left(\cos \alpha + \frac{d}{L}\right)$$

L - length of plates

Normally the relationship between α, d and L are such that d/L is negligible. Hence

$$\frac{q}{W.L} \leqslant V_s . \cos \alpha$$

Now q/WL is analagous to the Hazen's surface loading for a conventional clarifier with V_s cos being the component of the settling velocity at right angles to the bulk direction of flow. If goes to zero cos goes to 1 and we have the conventional surface loading rate.

To facilitate a comparison to a conventional clarifier let us look at the conventional surface loading rate Y

$$Y = \frac{q}{d.w} \qquad \frac{(\text{flow})}{(\text{cross-sectional area})}$$

Developing and simplifying with the settling time equation from above.

$$Y \leqslant V_s \quad . \frac{L}{d} . \cos \alpha$$

Hence we see that surface loading rate in inclined plate clarifiers

is effected by the settling velocity V_s , the length of the plates, L, the distance between the plates d and the angle of elevation α. Minimum plate spacing has been found by experience to be 1.5 inches.

The upper limit on plage spacing is determined by the fact that the flow should be laminar. In rectangular shaped cells Reynolds numbers below 500 are laminar with the transition range considered to be $500 < R_e < 2000$.

In order to assure a stable flow, reference can also be made to the Froude (F) number, a dimensionless ratio of inertia forces to gravitional forces. It is best to be at a value of 10^{-5} or less.

$$R_e = \frac{VR}{\mu}$$

$$F = \frac{V^2}{g\ R}$$

μ - kinematic viscosity

g - acceleration due to gravity

R - hydraulic radius of the flow channel.

By solving these equations the plate spacing and angle of inclination relationship is established. By applying Reynolds number and Froude number constraints the critical clarifier parameters can be determined.

To ensure the viability of this theoretical approach specific attention is paid to achieving flow distribution equally between all the plates and also flow distribution across each plate.

SIZING

Information required to size inclined plate clarifiers includes

1) feed rate of waste effluent

2) settling rate of the solids. This is determined through extensive settling tests optimizing on flocculant type and dosage.

3) supernatant quality (suspended solids)

4) sludge underflow concentration (suspended solids).
Both 3) and 4) are obtained by lab or pilot testing.

APPLICATIONS.

Inclined plate clarifiers can be applied to many waste applications. Industrial applications are found in steel mills for a variety of uses including mill scale sedimentation. Pulp and paper plants have various applications and particular success has been achieved with bark fines removal from wood room effluent. This has been demonstrated in Consolidated Bathurst's Port Alfred Mill (Quebec) with an Axel Johnson inclined plate separator/thickener.

Table 1 - Based largely on European experience, shows the performance levels achievable.

Our own experience has been concentrated on pulp and paper, steel industry, food processing, metal plating and filter backwash clarification.

Our first two installations have been in the electroplating industry and start up is currently underway. Table 1, last column, illustrates the supernatant and sludge concentration achieved. Refer to Fig. 4 for a photo of a typical inclined plate clarifier.

One particular company was faced with a direction from their town to clean up their effluent discharge as they were considered to be a major contributor to the total suspended solids entering the municipal sewage plant on a daily basis. The company had insufficient real estate for a conventional clarifier and was also under a time constraint from the municipality. Within this background an inclined plate clarifier was selected. A flow schematic of this installation is shown in Fig. 5.

Advantages of inclined plate clarifiers can be summarized as follows:-

1) efficient clarification
2) low volume retention in the clarifier
3) easy sludge removal
4) simplicity of operation

5) no moving parts resulting in low maintenance and power requirements
6) reduced floor space - as low as 10% of conventional clarifiers
7) modular construction - factory prefabricated models resulting in ease of transportation and installation
8) low capital costs - installed cost comparisons to conventional clarifiers show savings in excess of 50%
9) quick construction and installation: 12 - 16 weeks

FILTER PRESS DEWATERING.

Introduction

The basic purpose of the filter press in the area of waste treatment is very specific: to retain the solids within the filter media and press these solids to a high concentration.

Filter presses have long been used in such process industries as pigment dyestuff preparation, juice polishing, electrolytic metal refining, sugar refining and many others.

For sludge dewatering typical North American approaches have been to use vacuum filters and centrifuges. Europe has, in contrast, made extensive use of filter presses. The demand for drier sludge cakes has been the prime reason for the recent local interest in the filter press. Moreover, mechanization and automation of the filter press has overcome its alleged traditional shortcoming of being labour intensive.

In North America there are a number of filter presses available from manufacturers such as Poly Filters, W.R.Perrin, Schriver Envirotech, Passavant, Edwards and Jones, Johnson Progress, and Dart Industries.

PRINCIPLE OF OPERATION.

The basic design of the filter press can be observed by reference to Fig. 6. The filter press consists of a steel skeleton with two end supports joined by two parallel side bars. These side bars

also provide the support member for the recessed plate chambers. One end is referred to as the fixed or feed head, the other the closing head. A closing mechanism such as an hydraulic ram or screw drive operates from the closing head to move the recessed plate chambers together and exert a closing or clamping pressure forming a series of filter chambers.

A plate transport mechanism located on each side bar is used after a filtration cycle to open the filter press. The closing head opens and each plate is individually separated from its adjacent plate and transported along the sidebars. This enables the cake formed to be released from the plates and fall on to a collection arrangement, such as conveyors, or directly into the sludge cake disposal container.

The actual filtration process is illustrated in Fig. 7. Each recessed chamber plate face has a filter cloth mounted so as to form a cavity for sludge capture. Each plate is provided with feed and drainage ports aligned so that continuous passages are formed when the press is closed. The surface of each filter plate is designed for drainage of the liquid pressed from the sludge. Ribs or grooves of pyramidal or cylindrical shape on the plate face provide a support surface for the filter media. The sludge water (filtrate) passes through the filter media along the drainage surface to the drainage ports.

The sludge feed enters via the feed inlet which can be located in the centre or any of the corners. The sludge first fills the cavities enveloped by the filter media. Under pressure a clear filtrate passes through the filter media and a cake begins to form from the media inwards. The end of the filtration cycle is determined by a pressure build up or a low filtrate flow.

Operating pressures of filter presses normally are 70 - 100 psig. Some high pressure presses of 200 to 225 psig. are now available.

NEW DEVELOPMENTS IN FILTER PRESSES.

Major developments in filter presses making them of particular

interest today include the automatic closing and opening of the filter press by use of an hydraulic ram or driving screws. Further, plate transport has been mechanized. On side bar presses this is achieved by use of an endless chain with attached triggers which pick one plate at a time and move it across the press opening.

One of the most significant developments has been in the area of filter press plates. Traditionally filter presses were supplied alternately with plates and frames. The frame provided the cavity when sandwiched between two plates. In this configuration the sludge would remain intact in the frame when the press opened up. The cake then had to be manually knocked out of this frame. To achieve automatic discharge of the sludge cake, recessed plates were developed. Each plate now forms a whole cavity, one-half hollowed out of each side. Refer again to Figure 7. This facilitates automatic cake release when the press opens.

The materials of construction have developed from the original cast iron and wood plates. Cast iron plates were very heavy and subject to corrosion. Wooden plates were used in some corrosive environments but limited life was always a factor with replacement being required every 1 - 1½ years of use. Steel reinforced synthetic rubber moulded plates were introduced and have many years of successful operation. Fiberglass plates are also currently manufactured. Polypropylene plates have received considerable attention particularly in North America where successful operation has been achieved over the last four years. Polypropylene plates offer excellent corrosion resistance, lightweight, reduced wear on filter media, and ease of cleaning.

At the heart of a filter press is the filter media. It is very important to match the filter media to the sludge to be filtered. The filter media is normally called filter cloth. Synthetic fibres have greatly expanded filter cloth materials from cotton, jute, flax, wool and paper to now include polypropylene nylon, polyethylene and others. The filter cloth fabric is usually in woven form. The filter cloth is cut, sized and punched to order. These cloths then are draped over the top edge of a plate covering both sides or may be

attached to pegs on the top edge of the plate.

These new materials of construction have resulted in improvements such as -

1. excellent corrosion resistance,
2. improved wear characteristics for long cloth lifetime (1½ years), and
3. elimination of filter aids such as diatomaceous earth in many cases by use of synthetic felt type fabrics.

Optimum cloth selection may be achieved by testing with a pilot filter press. (Fig. 8).

SIZING.

Sizing filter presses is accomplished by calculating the volume of cake space required and the filtration rate. The filtration rate is best obtained by performing actual test runs on the waste sludge on a laboratory or pilot filter press. Excellent experience has been reported with scaling up of the filtration process from pilot scale filter presses (6" x 6") to full size presses (48" x 48").

The filtration rate is $F = \frac{Vc}{t.\ A}$

where F filtration rate (feed rate)

Vc-volume of sludge feed
t-elapsed time
A - surface area of filter media

From the average filtration rate over the filtration cycle the press cycle time can be calculated. This press cycle time includes filtration time, plus press opening time, plus cake discharge time plus press closing time. From this total filter press cycle time

the anciliary equipment can be sized. This includes sludge storage tanks, sludge pumps, etc.

The volume of sludge cake cavity required is also calculated from the lab or pilot tests. The sludge cake obtained is analyzed for total moisture content to ensure that a satisfactory concentration can be achieved. From the total press time and the sludge production rate a total gallonage to be filtered is calculated. Then the volume of the sludge cake cavity may be calculated.

$$V_{sc} = (V_{psc}) \cdot \frac{V_s}{V_{ps}}$$

V_{sc} - volume of sludge cake cavity

V_{psc} - volume of pilot sludge cake cavity

V_s - volume of waste sludge to be pressed per cycle

V_{ps} - volume of waste sludge pressed in pilot study

From a knowledge of the volumetric cavity of various plate sizes the number of plates can be determined.
Typical filter press performance is illustrated in Table 2.

Table 2

Type of Sludge	Percent Cake Solids
Potato waste sludge	35 - 55
Tannery secondary waste	30 - 40
Metal hydroxide (Al, Fe, Zn).	25 - 45
Anaerobically digested sludge	25 - 35

The advantages of filter presses can be summarized as follows. -

1) Filtration efficiency remains good even with a sludge feed of substantially varying characteristics.

2) Improved filtrate quality (lower suspended solids)

3) Driest sludge cake

4) Ease of handling a dry cake
5) Wide choice of materials of construction for the parts in contact with the sludge to match its corrosion and abrasion characteristics
6) Wide choice of filter media
7) Low maintenance of the filter press because of few moving parts
8) Low energy consumption
9) Low manpower requirements with automated filter presses
10) Capital costs are very competitive.

In conclusion it can be seen then that both the filter press and the inclined plate clarifier are two unit operations that will attract attention for wastewater treatment over the next few years.

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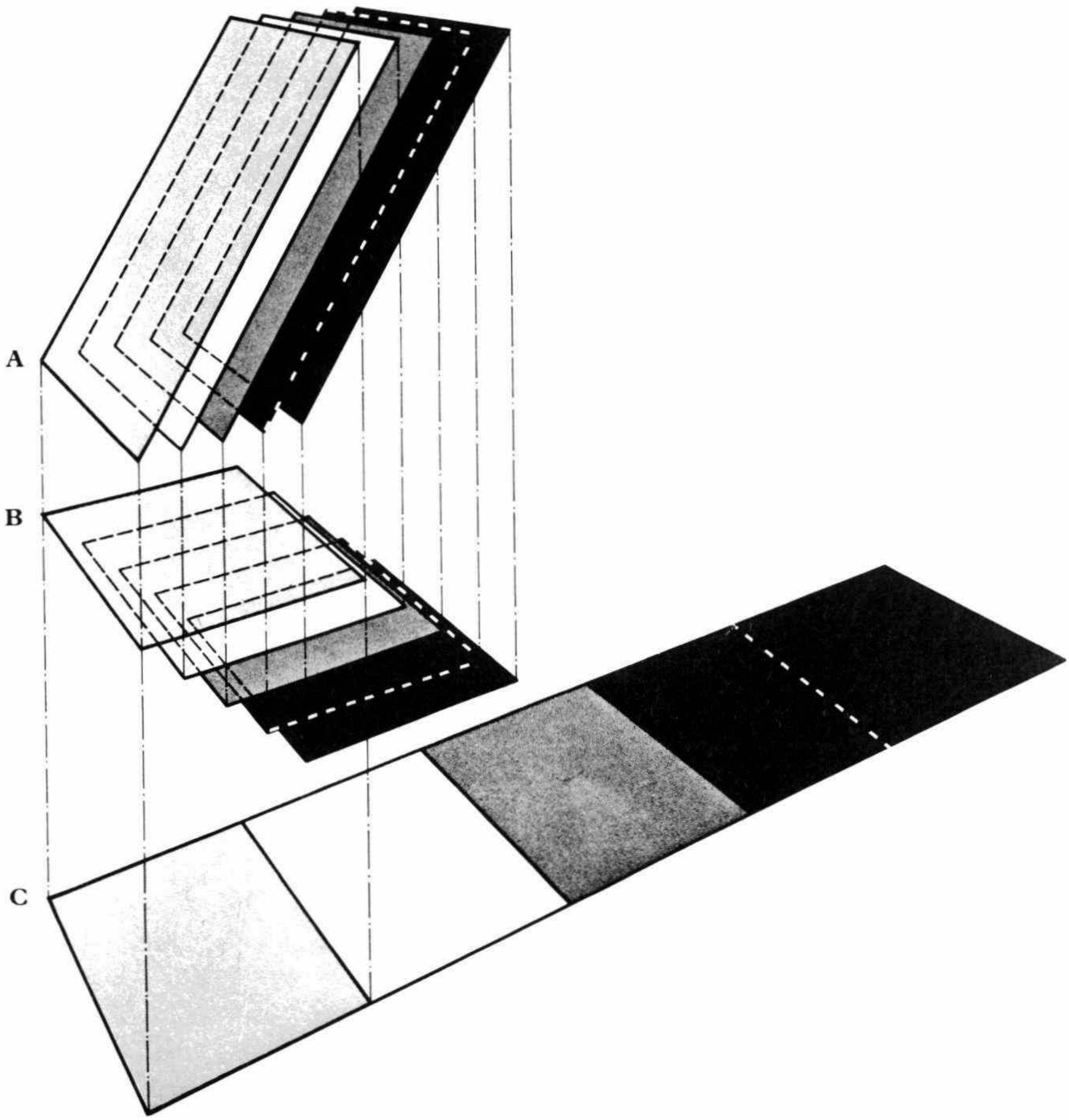


Figure 1: Horizontal projections of inclined plates

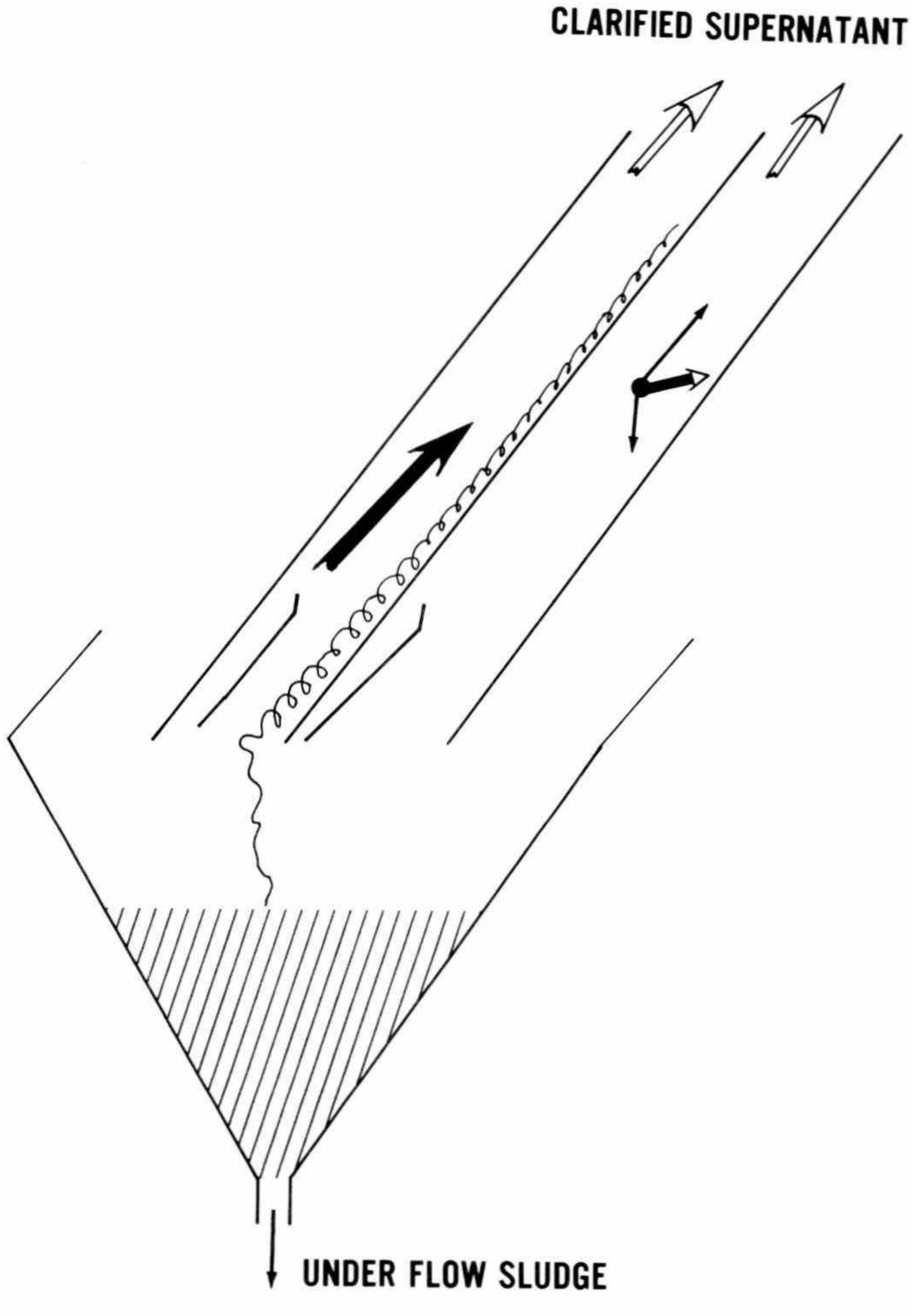


Figure 2: Principle of operation

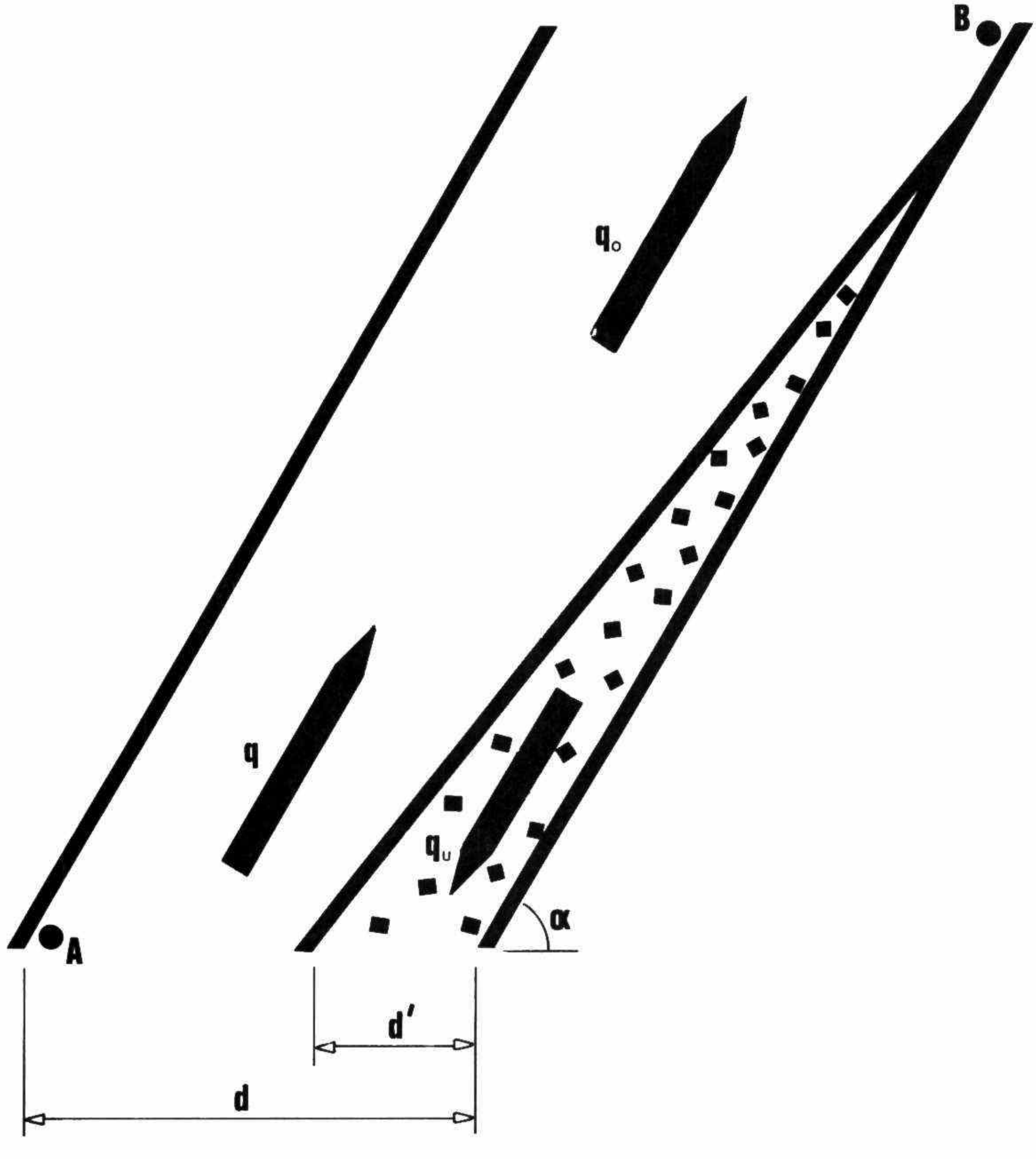


Figure 3: Flow profile schematic

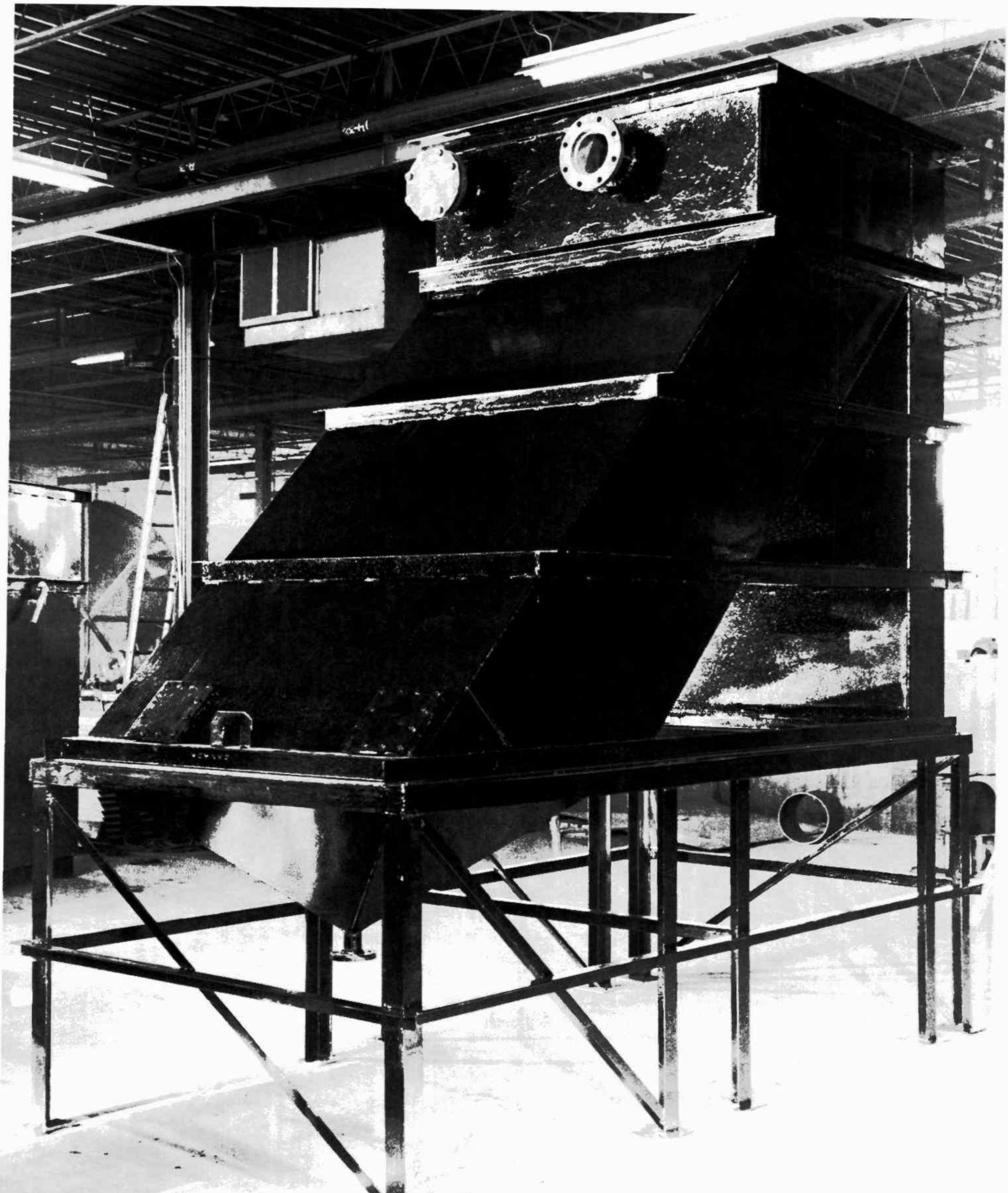


Figure 4: Typical Inclined Plate Clarifier

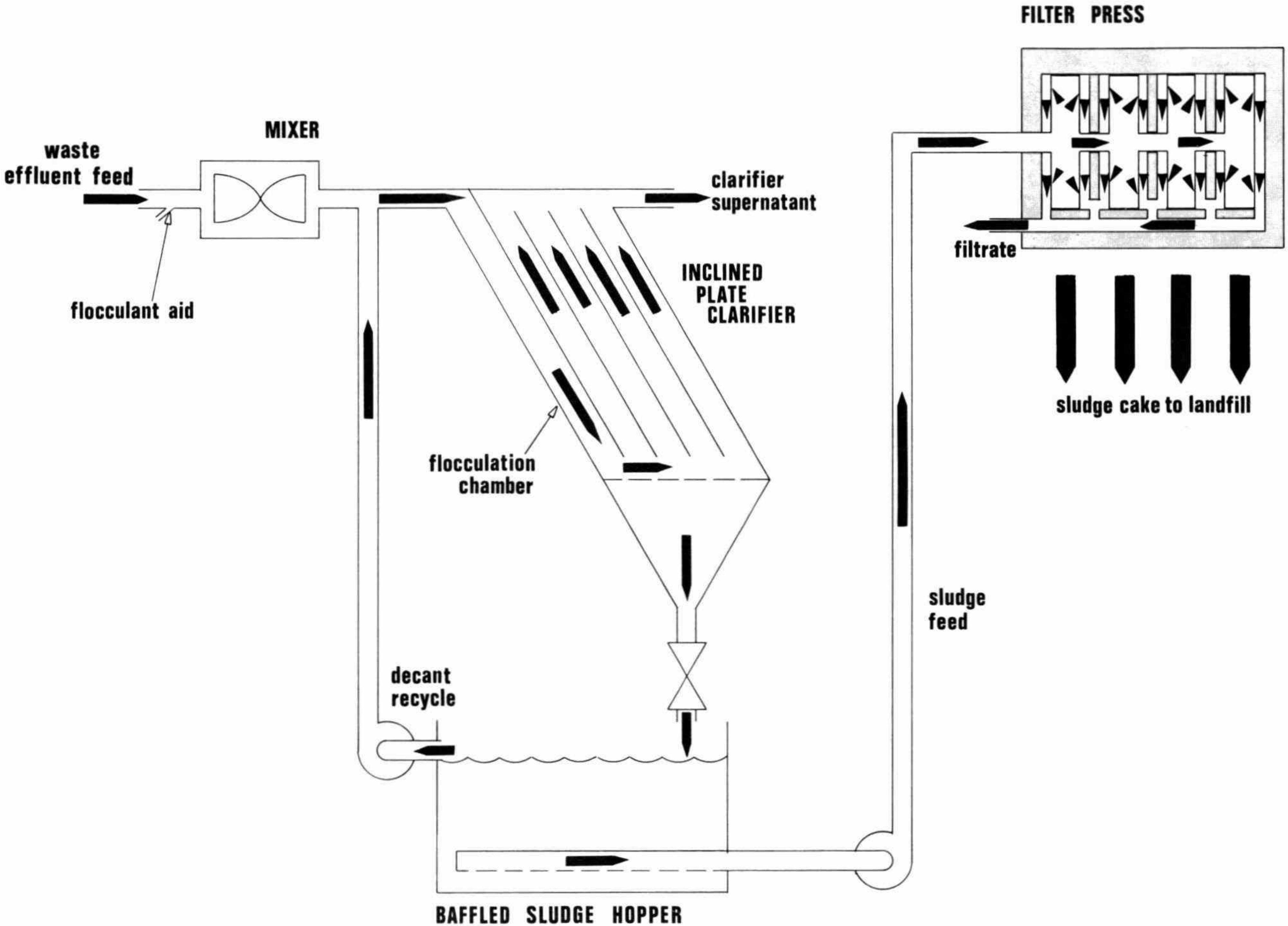


Figure 5: Schematic of Inclined Plate Clarifier and Filter Press System

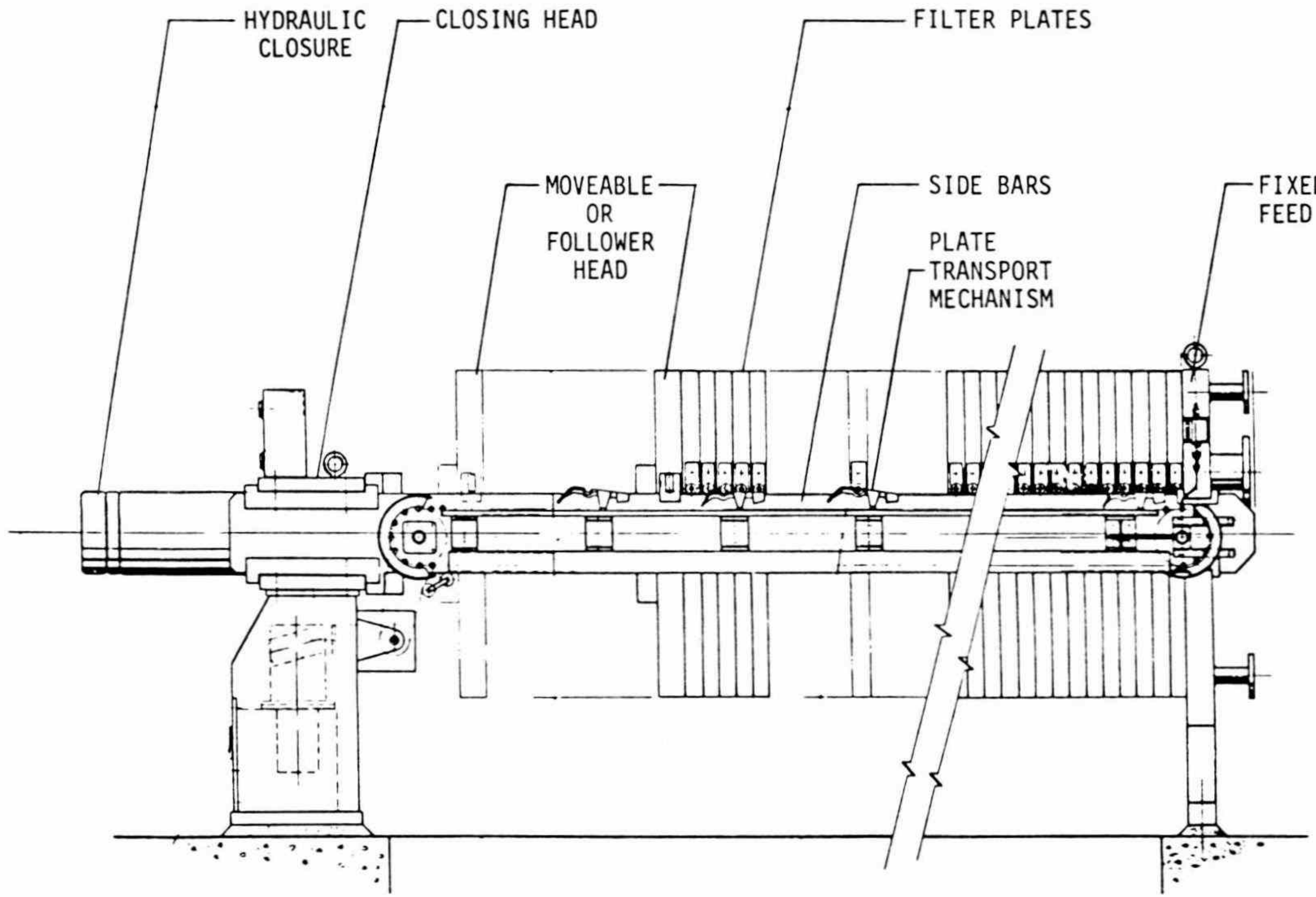
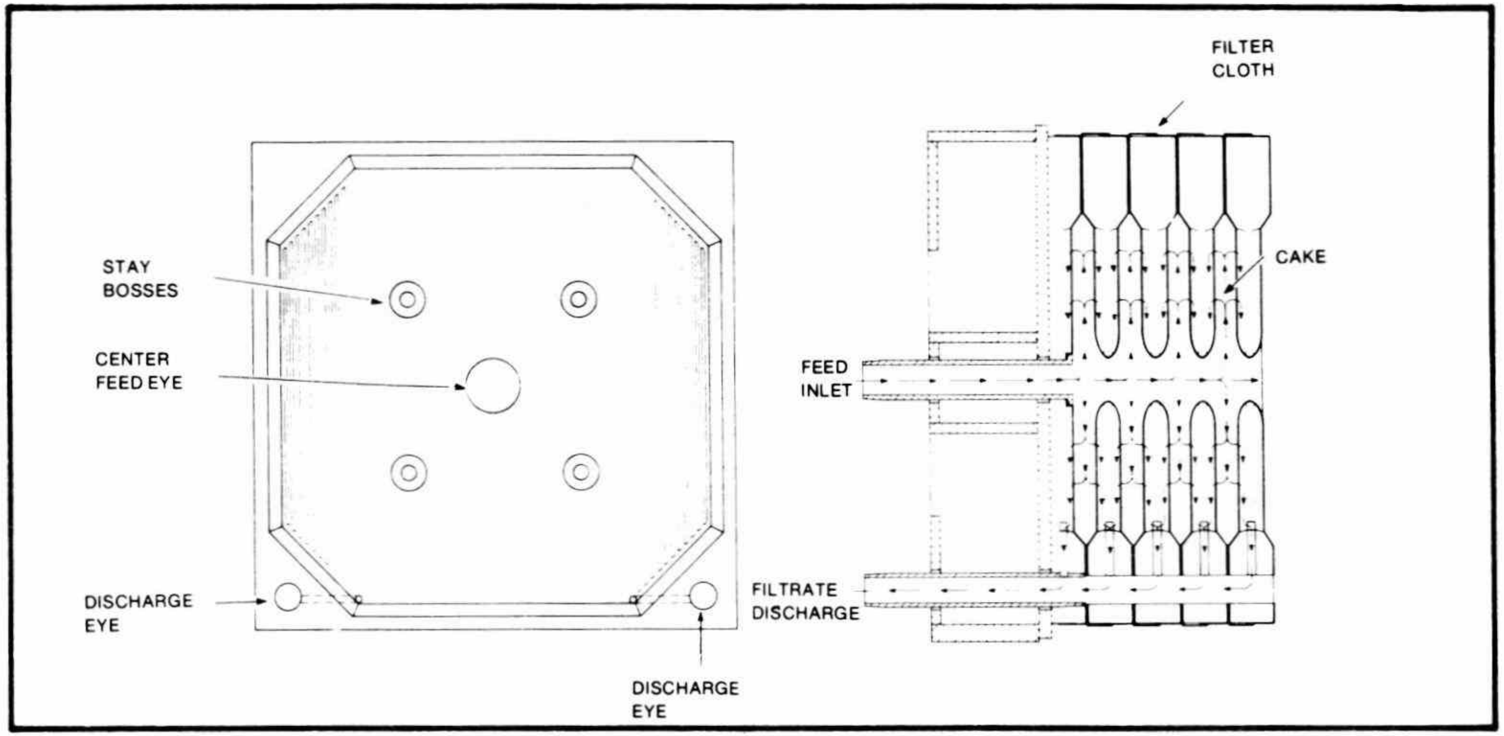


Figure 6: Filter Press schematic (Courtesy W.R. Perrin)



TYPICAL CENTER FEED CLOSED
DISCHARGE RECESSED CHAMBER PLATE

RECESSED CENTER FEED DIAGRAM
SHOWING FLOW PATH DURING FEED

Figure 7: Recessed plate chambers (Courtesy Poly Filters)

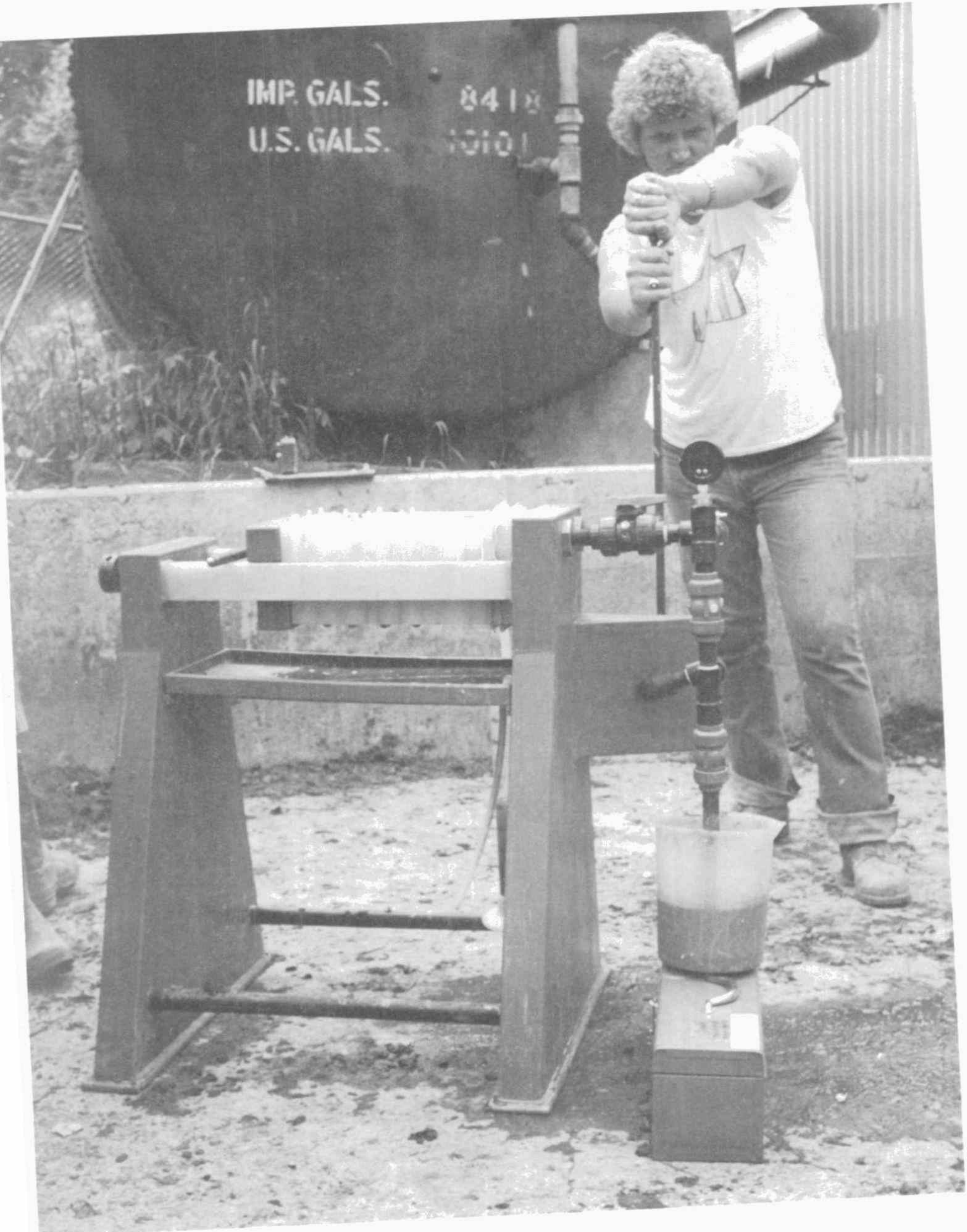


Figure 8: Laboratory Filter Press - on-site testing

Application	Rinse water Copper & brass Pickling	Rinse water Stainless steel Pickling	Paper mill effluent	Municipal Sewage	Electroplating Claripak
feed rate Igpm	90	200	300	200	50
coagulant aid	yes	yes	yes	yes	yes
feed quality ppm	≈ 200	100–1000	300–500	100	1400
Supernatant quality ppm	< 10	< 10	< 20	< 5	< 6
Underflow sludge ppm	20,000	20,000	20,000–60,000	≈ 5,000	≈ 8,000–15,000

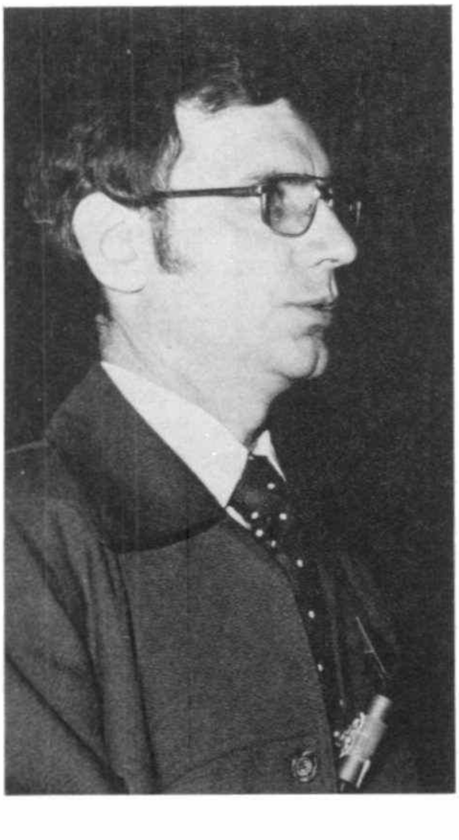
Table 1: Performance of Inclined Plate Clarifiers

DEVELOPMENT AND IMPLEMENTATION OF AN IMPROVED WASTE WATER TREATMENT SYSTEM AT IMPERIAL'S SARNIA REFINERY

An extensive and costly program to upgrade the wastewater treatment capability at Imperial's Sarnia Refinery was initiated in 1970. The major features of the program, which proceeded in several phases, included:

a) A comprehensive program to segregate sewer systems with a view to minimizing the volume of contaminated water requiring further treatment.
b) Installation of a dual-media gravity flow filtration system for secondary removal of oil and suspended solids.
c) Installation of an activated sludge plant to remove a substantial portion of the dissolved organics from the refinery effluent.

This paper discusses the various developmental and pilot studies that were carried out and describes the design details of the treatment systems installed. In addition, actual operating experience is compared to predicted performance and regulatory objectives and guidelines.



by

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DEVELOPMENT AND IMPLEMENTATION OF AN IMPROVED WASTE WATER TREATMENT SYSTEM AT IMPERIAL'S SARNIA REFINERY

BY

G. W. Schindel

In 1897, the Imperial Oil Company Limited bought a refinery built in Sarnia in 1871 by the Dominion Oil Company. The company dismantled its Petrolia refinery, moved the equipment to Sarnia and combined the two plants into a 900-barrel-a-day operation. Thus began the story of Imperial's refinery at Sarnia - the location of uninterrupted refining of crude oil for over 100 years now.

Tremendous changes have, of course, taken place during those years. Sarnia Refinery today with its capacity approaching 140,000 B/D of crude represents one of the largest and most complex refineries in Canada. Production comprises a complete range of petroleum products including gasolines, jet fuels, diesel fuels, heating oil, bunker fuels, lubricating oils, greases, waxes, etc. In addition, feedstocks are supplied to adjacent Esso Chemical facilities for production of aromatics, ethylene and a variety of other petrochemical products.

The complex contains nearly all available refinery type processing units including such major units as Atmospheric and Vacuum Distillation, Catalytic Cracking, Fluid Coking, Hydrocracking, Hydrogen Synthesis, Powerforming (reforming), Hydrofining (hydrogen treating), HF Alkylation, Lube Oil and Grease Plants, Sulphur Recovery, etc. Many of these units are the most modern in design, being installed during a major expansion and modernization program extending from the mid 1960's to the early 1970's. On the other hand, some facilities still in use are over 50 years old.

The growth and changes in refinery operations over the years has required a continuing re-evaluation and modification of waste water treating systems. Some of the more recent activities and treatment programs have been described in the earlier years of these conferences. Despite such on-going activities, however, it became obvious in the late 1960's that a further major expansion of the waste water treating facilities would be required. The recent refinery expansion and modernization program tended to overtax the existing treatment system at the same time as regulatory requirements were becoming more stringent in response to a growing public awareness and pressure in the environmental area. Consequently, intensified studies were initiated in 1968/69 to develop and implement an improved waste water treatment system at Sarnia Refinery. The major stages of the program which will be emphasized in this paper included:

a) A waste water segregation program to minimize the volume of contaminated water requiring further treatment.

b) Installation of a filtration system for secondary removal of oil and suspended solids.

c) Installation of an activated sludge plant.

2. WASTE WATER TREATMENT SYSTEM - 1969

2.1 General

The processing area of Sarnia Refinery is situated on a strip of land running North-South adjacent to the St. Clair River at the southerly extreme of the city of Sarnia. The northerly portion known as Area I comprises about 110 acres while the southerly portion (Area II) contains approximately 155 acres. In addition, a storage area known as Scott Road Tank Farm (SRTF) is located about 1 mile inland to the east of Areas I and II. The SRTF covers 180 acres and contains the bulk of the refinery's crude and finished product storage.

Areas I and II contribute the vast majority of the refinery's contaminated waste water. The effluent from SRTF is essentially storm runoff, although some contamination occurs due to draining of tank bottoms.

2.2 Segregated Collection and Treatment Systems - Areas I and II

The waste segregation and treatment systems in place in 1969 are shown schematically in Figure 1. They consisted of:

a) Sour Phenolic Water - Process waters with a "high phenol" content (generally about 25 - 500 ppm) and generally also high in H2S and NH3 were collected in a separate system of overhead piping. The combined streams, after routing through a Sour Water Stripper for removal of H2S and NH3, were subjected to bio-oxidation in a package unit known as an "aero-accelator". The development and startup of this system in 1954 was a pioneering achievement in the Canadian Refining industry. Bio-oxidation, however, was discontinued during the period 1959-68 and replaced by deep well disposal of the phenolic waters.

b) Spent Caustic - Caustic scrubbing solutions are used in the refinery treating processes to sweeten various products, i.e. to remove sulphur compounds. Two types of spent caustic are generated, namely Cresylic and Sulphidic. Separate collection systems were in place with the Cresylic Spent Caustic being sold to a chemical reclaiming company for recovery of the "acid oils" while the Sulphidic material was disposed of in the refinery deep wells.

c) Clean Water Sewer - This sytem was designed to handle only clean once-through cooling water. Over the years, however, some random use of this sewer system allowed the introduction of some contaminated water.

While the newer units have been designed for minimum water use (air cooling plus cooling towers) the older units use large volumes of once-through cooling water - up to about 45 MM IGPD.

The clean water sewers terminated in one of three API gravity separators with the separator effluent discharging to the St. Clair River.

d) Oily Water Sewer - designed to accept contaminated process wastes (excluding phenolic water and spent caustic). The system was also designed to handle all storm water and ships ballast. In addition, large volumes of once-through cooling water entered this system. The oily water sewers again terminated in one of three API gravity separators designed for removal of oil and suspended solids. The separator effluent was discharged to the river.

e) Sanitary Wastes - Sanitary wastes in Area I were collected in a separate sewer and fed to the City of Sarnia sewage treatment plant. Since a main city sewer was not yet available to serve Area II, septic tanks were used in this part of the refinery. Septic tank overflow entered the oily water sewer.

2.3 Collection and Treatment System - SRTF

One half of the tank farm was serviced with an oily water sewer leading to a small gravity oil-water separator. The separator overflow entered an impounding basin. A portion of the drainage from the other half of the tank farm discharged directly to a drainage ditch known as the County Ditch. Since oil contamination of these waters could occur the entire flow of the County Ditch was routed through the impounding basin with the effluent re-introduced into the County Ditch, ultimately leading to the St. Clair River.

2.4 Major Problem Areas - 1969

a) Oil Discharge - As noted, only primary, gravity separating facilities were available to remove oil from the oily water effluents in Areas I and II. Because of the high flow rates through the separators, the presence of oily water emulsions, etc., higher than desirable discharges of oil were experienced.

Similarly at the SRTF, high flow rates in the County Ditch during rainstorms tended to carry over significant quantities of oil from the impounding basin.

In addition, other miscellaneous sources resulted in further occasional contributions along the area of the loading docks.

b) Suspended Solids - Again gravity separation alone proved inadequate in dealing with solids in the Area I and II oily water effluents. This was particularly the case during occasional plant upsets such as in desalter operation which could contribute undesirable amounts of an oil/solids/water emulsion to the sewer system.

A second problem involved the direct discharge to the river of a lime sludge from the water treating section of the Utilities Plant.

c) Deep Well Disposal - During the late 1960's concerns were being expressed regarding the advisability of waste disposal by pressure into the relatively shallow Detroit River formation. As noted a bio-oxidation system to treat phenolic waters was recommissioned in 1968. However, frequent upsets of the plant were being experienced. During these periods and during the occasional shutdowns of the Sour Water Stripper significant volumes of phenolic waters were disposed of in the refinery deep wells along with the relatively minor quantities of Spent Caustic.

d) Phenolic Materials - Total discharge of phenol in the early 1970's averaged in the order of 25-30 lb/day - a significant achievement considering the magnitude of the refinery operation. This level, however, was being accomplished at the expense of undesirable levels of deep well disposal and an extremely demanding schedule in day to day control activities. Furthermore, this average level was still about three times the Ministry's concentration objective of 20 ppb.

e) Dissolved Organics - By the late 1960's, increasing emphasis was being exerted by the Ministry regarding the need to reduce discharges of "dissolved organics". Prior to this time, efforts had been directed towards reducing discharges of specific compounds, e.g. phenol, which were known to cause undesirable effects. The growing level of industrial activity in Sarnia's Chemical Valley, together with a general increase in knowledge regarding potential sub-lethal effects of organics, e.g. fish tainting, led to this change in emphasis.

Sarnia Refinery had no capability for removing dissolved organics, other than from those segregated streams being bio-oxidized for removal of phenol.

3. DEVELOPMENT AND IMPLEMENTATION OF NEW TREATING FACILITIES

An overall assessment of the waste water treatment system in 1969 indicated major shortcomings and a need for further facilities to provide for secondary removal of oil and subsequent treatment to remove dissolved organics. It was obvious that both steps would be extremely expensive (if at all feasible) at the then prevailing flow rates of contaminated water. The first requirement, therefore, was a program to significantly reduce waste water flows. A preliminary timetable for these major phases was established as follows:

Phase I	- Waste Segregation (reduction) in Area II	- 1972
Phase II	- Waste Segregation in Area I plus Secondary Oil Removal System	- 1973
Phase III	- Dissolved Organics Removal	- 1975

A large number of other projects proceeded concurrently with the development and implementation of the above three phases. Some of this work will be briefly noted later in the paper.

3.1 Phase I - Waste Segregation in Areas I and II

The total dry weather discharge of contaminated water from separators 5, 10 and 11 in 1969 was in the order of 15,000 usgpm. While it was known that this volume contained substantial quantities of clean water, the sources and volumes were not defined. Consequently, technical manpower was assigned early in 1970 to survey the refinery to:

a) determine the source of all waters entering the sewer systems.
b) distinguish between contaminated and clean waters, the latter defined as having no direct contact with oils or other hydrocarbon.
c) estimate flows of each individual source.
d) determine sewer system and separator receiving stream. This objective required considerable work with dyes, etc. since in many cases drawings were inadequate.

The study proved to be very time-consuming requiring some 12 man-months of technical effort. The result, however, was a very thorough and detailed analysis of the sources and disposition of waste waters and an excellent base for future planning.

The study revealed that of the 15,000 usgpm, about 12,000 usgpm could be classed as clean water. That is, the flow of contaminated water requiring further treatment could be reduced to 3,000 usgpm by diverting all the clean water from this sewer system. Once through cooling water from various heat exchangers, represented about 65% of the water which could be diverted. The remaining 35% was indicated to come from a great many individual sources including compressor jacket and pump cooling water, steam condensates from tank heaters and line tracers, sample coolers, boiler blowdown, etc.

Despite some skepticism concerning achievement of the total indicated level of diversion it was obvious that a substantial flow reduction was possible. Consequently, a project schedule was developed which prioritized timing of individual steps on a cost/benefit ratio and also considered other factors such as timing of unit shutdowns, manpower availability, etc. The original projections for the project indicated a December 31 1973 completion. Implementation in the field, however, proved considerably more difficult than anticipated with a delay of 1-1.5 years being experienced. Nevertheless, from a process point of view the project has been a resounding success- achieving a reduction in flow of contaminated water to the present normal level of 3500-4000 usgpm.

Some thought was also given to providing a separate system for "clean" storm water. This did not appear practical, however, on a cost/benefit basis.

Several sources of contamination of the clean water sewers were discovered and diverted to the oily sewer. Also, new collection sewers for sanitary wastes from Area II were installed and tied into the City of Sarnia system when it became available in 1973.

3.2 Phase II - Dual Media Filtration

As previously noted, the objective was to have a secondary oil removal facility in place by December 31, 1973. Slower than expected progress in waste segregation, however, necessitated a delay of the required pilot studies. Even so, substantial quantities of "clean water" diluted the waste when the pilot program was initiated in late 1972.

(i) Pilot Study of Dual Media Filtration

During the late 1960's/early 1970's considerable interest and promise emerged in the use of filtration for removal of oil as well as suspended solids. Successful experience had been demonstrated in a few steel mills and oil refineries. Further

promising data was available from extensive pilot studies at another Exxon Refinery as well as from the adjacent Sarnia Esso Chemical Operation.

The available information indicated several major advantages in the use of filtration versus the more generally applied air flotation. These were:

a) More efficient removal of suspended solids along with equal or better oil removal without the use of chemicals.

b) Ability to handle a wide range of flow rates.

The latter advantage was of particular interest to Sarnia because of limited real estate for provision of storm holdup.

The pilot filtration unit employed was rented from Eimco Envirotech Limited and represented a scaled down version of a commercial unit. The 4-foot diameter tower contained a bed made up of 2 feet of anthracite over 1 foot of sand. The feed, obtained from #14 API Separator was pumped to a head box and flowed by gravity downflow through the media.

Some 40 "runs" were conducted during the 3 month pilot program. Each run consisted of the filtration cycle followed by a backwash cycle to remove accumulated oil and sediment. Most of the studies were done at a filtration rate of 4 usgpm/ft^2 (a typical rate for the commercial unit). Testing of higher rates was carried out as well to establish an upper limit.

The average results obtained are shown below:

	Influent	Effluent	% Reduction
Oil - ppm	33	8	76
Suspended Solids - ppm	29	13	55

Duration of the filtration cycle varied depending on flow rate and feed water quality. At a flow rate of 4 usgpm/ft^2 and the average feed conditions shown, run lengths of about 24 hours were experienced.

Limited testing of the backwash water indicated that the bulk of the deposits were removed from the media in the first two minutes. Gravity settling of the backwash water showed that the "rapid" settling of the contaminants was essentially complete after 2 hours. However, the water phase still contained significant concentrations of oil and suspended solids. Certain polyelectrolytes were shown to greatly improve the settling rate producing water of exceptional clarity in about five minutes.

(ii) Design of Refinery Installation

Based on the results of the pilot study and studies of other aspects an overall system as shown in Figure 2 was designed and installed using the Eimco SVG Dual Media Gravity Feed System. (Figure 4 provides a photograph of the filters).

The effluent from each of the oily water separators No. 5, 10 and 14 is pumped to a common filtration facility located in Area II. In addition to the filter feed pumps, storm water storage tanks and pumps were installed at each separator. One tank was sized to also serve as a ballast tank.

The filtration plant was designed for a dry-weather flow of 6,000 usgpm - the early 1973 projection of ultimate flow following waste segregation. Based on the pilot studies a design feed rate of 4 usgpm/ft^2 was specified. The installation consists of 6-18 foot diameter vessels with filter beds consisting of 2 feet of anthracite over 1 foot of sand.

The pumping and storm water storage facilities were designed such that satisfactory filtrate quality could be maintained under storm conditions although increased backwash frequency would be required.

The feed enters an elevated splitter box which divides the flow into six streams. The filtration and backwash cycles are initiated automatically by a sequence controller. Butterfly valves using air operators are used throughout. Air for the air scour step is supplied by a blower. The backwash frequency is controlled by a setting of a master timer in the sequence controller. A high pressure override, however, was built into the system to initiate backwash on a particular filter if "premature" fouling occurred.

The backwash water storage compartment on each filter stores 20,000 usg of water which during backwash is discharged over a period of about 5 minutes to a 100,000 usg sump. Water from the sump was designed to be pumped to one bay of No. 14 separator to provide about 24 hours of gravity separation for the oil and suspended solids with the "clarified" water being recycled to the filters. It was recognized that this was likely a minimal system for handling backwash, however, it was decided to evaluate the backwash water characteristics during full scale operation before committing to further facilities.

A new "Environmental Monitoring" building was included to house the controls for the filtration system as well as those for some of the existing facilities and the projected future phases, thus centralizing control.

(iii) Actual Operating Experience on Filtration System

Waste water flow was started to the plant in May 1974. Analysis of the influent and effluent during the period May to October yielded the following average results:

	Influent	Effluent	% Reduction
Oil - ppm			
Plant	56	12	79
Pilot Unit	33	8	76
Suspended Solids - ppm			
Plant	43	20	53
Pilot Unit	29	13	55

Flow rates during this period were in the range of 5-7,000 usgpm.

It is noted that the removal efficienty for both oil and suspended solids was very close to that predicted. Average effluent concentrations were somewhat higher than anticipated, however, because of significantly higher concentrations in the feed. This higher loading resulted in more rapid fouling of the filter beds and required an increased frequency of backwashing. Filtration cycle lengths during this period were about one-half the expected 24 hours. This in turn increased the volume of backwash water being recycled from an expected level of about 2% of the fresh feed flow to 4-5%. Part of the problem was due to a high return of oil and suspended solids to the filters in "clarified" backwash.

Consequently, the backwash handling system was revised as follows:

a) Provision was made to add a cationic polyelectrolye as the water is pumped from the backwash sump.

b) The water was then routed to an existing, elevated, cone-bottomed tank for sludge separation. The tank has provision for withdrawing the oily sludge from either the top or bottoms. The clarified water is withdrawn at an intermediate level and recycled to No.14 separator while the sludge is disposed of by incineration through an outside contractor.

These changes resulted in a substantial improvement in the filter operation.

A further measure of plant performance is shown in Figures 5 and 6, which give plots of the cumulative frequency of the effluent oil and solids concentration in 24 hour composite samples taken over a period August 1974 to April 1976. Note that oil concentration has been $<$15 ppm some 85% of the time, while a median suspended solids concentration of 25 ppm has been realized.

The system has required minimal operator attention as well as maintenance since startup.

One area recognized as a potential problem was that of media fouling. However, an inspection of the media in one filter in October 1975 indicated no media deterioration over the first 1.5 years of service. The media was clean with no visible evidence of formation of channels or agglomerates in the bed. The sand and anthracite were well distributed. A sieve analysis and comparison with the original analysis suggested the media to slightly more uniform in size, presumably due to a small loss of fines in the backwash.

3.3 Phase III - Removal of Dissolved Organics

As previously noted, the projected schedule indicated a facility for treating dissolved organics to be in place by the end of 1975. In order to meet this timing it was necessary to initiate pilot studies in mid-1973 even through the waste segregation projects and dual media filters were still under construction.

(i) Pilot Study of the Activated Sludge System

While activated carbon has had some application in refinery waste water treatment (mainly for polishing), biological oxidation is still the only available "practicable" process for large scale treatment of refinery waste water. Consequently, the major pilot plant program was directed at a study of the activated sludge system.

A consultant was retained to assist in the design of the pilot equipment, the design and conduct of the experimentation, the data interpretation and selection of the basic process design parameters. The pilot studies were conducted at Sarnia, however, by Imperial technicians under the routine direction of the Research Division in consultation with Sarnia Refinery personnel. This proved to be a highly satisfactory arrangement.

The objectives of the pilot plant work were to determine:

a) the design parameters for construction of the refinery plant.

b) the effluent quality to be expected after biological treatment.

c) the ability of the system to cope with "shock loading" of common refinery contaminants.

d) the effect of decommissioning the existing biological system treating the segregated high phenolic wastes.

The pilot work proceeded in three basic phases. The first phase conducted in the lab from July - October, 1973 established preliminary design data. This work employed as feed, composite batch blends of the effluent from the three oily water separators. Since significant "clean water" dilution was still present at this time the feed was spiked with more concentrated waste to simulate the final feed. The second phase (late 1973/ early 1974) extended this work to a study of shock loadings. The third phase was a field study using the same equipment but employing as feed the actual effluent from the refinery dual media filters following startup in May 1974. This phase was to confirm the validity of the design data obtained in phase I.

Three identical, continuous, bench scale pilot biox reactors (about 4 litre capacity) were operated in parallel. For phase I and II described above, a bench scale dual media filter was constructed of 3" diameter glass pipe.

It is worth mentioning that the 3" diameter filter gave better removal of oil (90%) and suspended solids (82%) than the 4' diameter pilot plant or the commercial unit, pointing out the danger of scale up of such equipment from small scale studies. It is known, on the other hand, that biological systems can be scaled up from bench scale with a high degree of confidence.

The major conclusions derived from the pilot studies were:

a) The combined waste water at Sarnia Refinery following dual media filtration is readily bio-degradable. A BOD reduction of 94% could be expected at the design basis of a 6 hour aeration time (dry weather flow). Operation at higher rates confirmed that satisfactory treatment would be maintained under anticipated storm runoff periods.

   Other design parameters and predicted effluent quality are shown in Tables 1 and 2 respectively.

b) The effluent quality at a 6 hour aeration residence time meets the Environment Canada Guidelines for Petroleum Refineries, including the fish toxicity test.

c) Treating the high phenolic waste waters along with the other contaminated water (i.e. decommissioning of existing biological system) produced a highly filamentous bulking sludge. Continued separate treatment of the segregated sour/phenolic water stream was recommended.

(ii) Design of Refinery Activated Sludge Plant

Based on the pilot studies the plant was designed and constructed with the following basic features: (photograph in Figure 7).

a) Two parallel aeration basins, with a total volume of 1.45 million US gallons. At the design dry weather feed rate of 4,000 usgpm, this provides a retention time of 6 hours.

b) Each aeration basin is equipped withtwo-60 HP fixed, "Lightnin" surface aerators, i.e. total of 240 HP.

c) The aeration basins overflow into 4-parallel rectangular clarifier bays, with a total surface area of 19,200 ft^2. The design dry weather overflow rate is, therefore, 300 usgpm/ft^2.

d) Settled sludge is removed by a "Clari-vac" travelling siphon system manufactured by Techology Inc. of Columbus Ohio. The siphons float on the clarifier surface and are drawn up and down the length of the clarifiers by a 1/3 HP variable speed, D.C. motor and stainless steel cables. Speed of travel is adjustable between 1-15 feet/min. Recycle rate is adjusted by varying the height of weirs in the individual siphon overflow boxes.

e) Total recycle sludge flows to the base of a 2-screw pumping station to be lifted to a head of 15'. The discharge flows by gravity to a splitter box in the aeration basin. Normally, only one screw would be used to provide a recycle rate of about 60%.

f) Two aerobic waste sludge digestors are provided each of 120,000 usg capacity. Aeration is by a diffused aeration system.

g) Tankage is provided to store phosphoric acid nutrient and caustic for digestor pH adjustment.

(iii) Activated Sludge Plant Operating Experience

Field construction began in August 1974. Despite a 3 month delay due to a construction industry strike the plant was completed in September 1975 - well in advance of the year end

commitment to the Ministry. Water was introduced during October with seed sludge from a neighboring refinery added October 30. By the end of November the mixed liquor suspended solids had increased to a level of about 1,800 mg/l.

Table 3 compares the predicted plant performance to preliminary actual data collected over the past few months. The data show an excellent degree of removal of dissolved organics, i.e. phenol, TOC and BOD (limited data). Furthermore, the plant (as predicted) is removing the acute toxicity of the refinery effluent towards rainbow trout fingerlings as determined by the required Federal tests.

The results have, however, been below expectation with respect to effluent suspended solids and removal of oils and ammonia.

The higher solids and oils have been due to poorer than anticipated sludge settleability as well as mechanical/electrical problems with the clarifier mechanisms. The sludge volume index has been improving and changes are being implemented to improve the operability of the clarifier and scum skimmer mechanism. With steady mechanical operation it will be possible to study and optimize the process variables such that the expected performance is obtained.

It is encouraging to note (see Table 4) that despite the difficulties during this initial operating period, the average refinery discharges are now well below the established Federal loading guidelines as well as the Provincial concentration guidelines on the effluent as discharged to the river.

3.4 Summary of Additional Major Projects

Some of the more significant additional projects implemented are briefly noted as follows:

a) No. 14 Gravity Oil Separator - Area II

A new 3-bay API separator was constructed in Area II. The oily water sewer flow is delivered to the separator by screw pumps. Rotary drum skimmers are installed for more continuous removal of recovered oil.

b) Improved Collection and Treatment at SRTF

A new sewer system was installed to remove all direct discharge to the County Ditch. A 2-bay oil separator was constructed in a portion of the Impounding Basin to facilitate oil recovery.

Studies are now underway to determine whether further treatment is required. If necessary, the impounding basin effluent will be pumped to the Area II activated sludge plant.

c) Dock Revamp

Modifications to reduce the risk of accidental spills included replacement of piping, additional motor-operated shutoff valves, new loading manifolds and provision of contingency facilities such as oil booms, skimmers, workboat, etc.

d) Lime Sludge Settling Basin

An idle pumphouse, located adjacent to the Utility Plant was modified to serve as a 2-bay settling basin for lime sludge generated in the hot lime boiler feed water softening process.

The clarified water is recycled to the raw boiler feed water surge tank while the settled sludge is removed to landfill.

e) Phase Out of Deep Well Disposal

A large number of projects were implemented to eliminate the use of the refinery disposal wells. Included were projects to reduce volumes and allow some reuse of phenolic waters and spent caustic, recommissioning of the 2nd "aero-accelator" and provision of additional feed and contingency storage tankage. A new sour water stripper is presently under construction. The existing tower will be maintained as a spare.

4. CAPITAL INVESTMENT

Overall investment in the waste water treatment program since 1969 has been $13.7 million in actual dollars. This is equivalent to some $20-21 million in 1976 dollars.

The program also required a large commitment of human resources. It is estimated that a minimum of 30 man-years of technical manpower was expended in the development and design of the overall program.

5. CONCLUDING COMMENTS

This paper has summarized the highlights of an extensive program to upgrade the waste water treating system of one of the largest and probably most complex refineries in Canada.

The program which was planned and implemented in several phases has demanded a heavy investment of capital and manpower. The constraints of working within an existing operating plant, dealing with a mixture of old and new plants, real estate limitations and a compressed implementation schedule all combined to significantly increase the technical challenge as well as costs for the project.

Despite these difficulties, however, the program now largely completed, has provided the refinery with a treatment system entailing the "best practicable" technology and which has the capability of meeting all current Provincial and Federal guidelines.

With the "facilities development oriented" program nearing completion, the emphasis at Sarnia Refinery will now shift towards a more intensive effort at optimizing operation of the waste water treatment system.

Figure I

AREAS I & II WASTE WATER TREATMENT - 1969

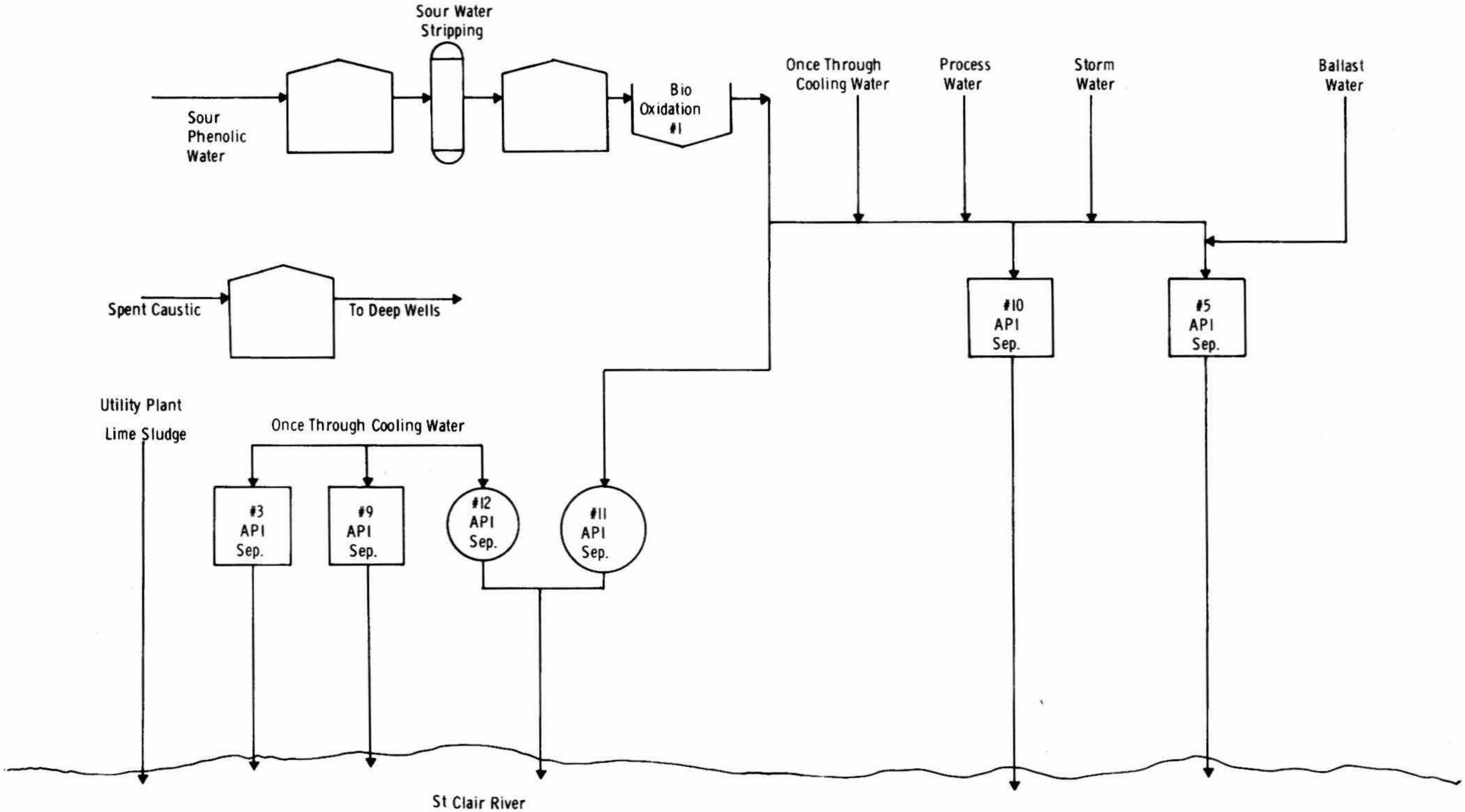


Figure 2

AREAS I & II WASTE WATER TREATMENT - PRESENT

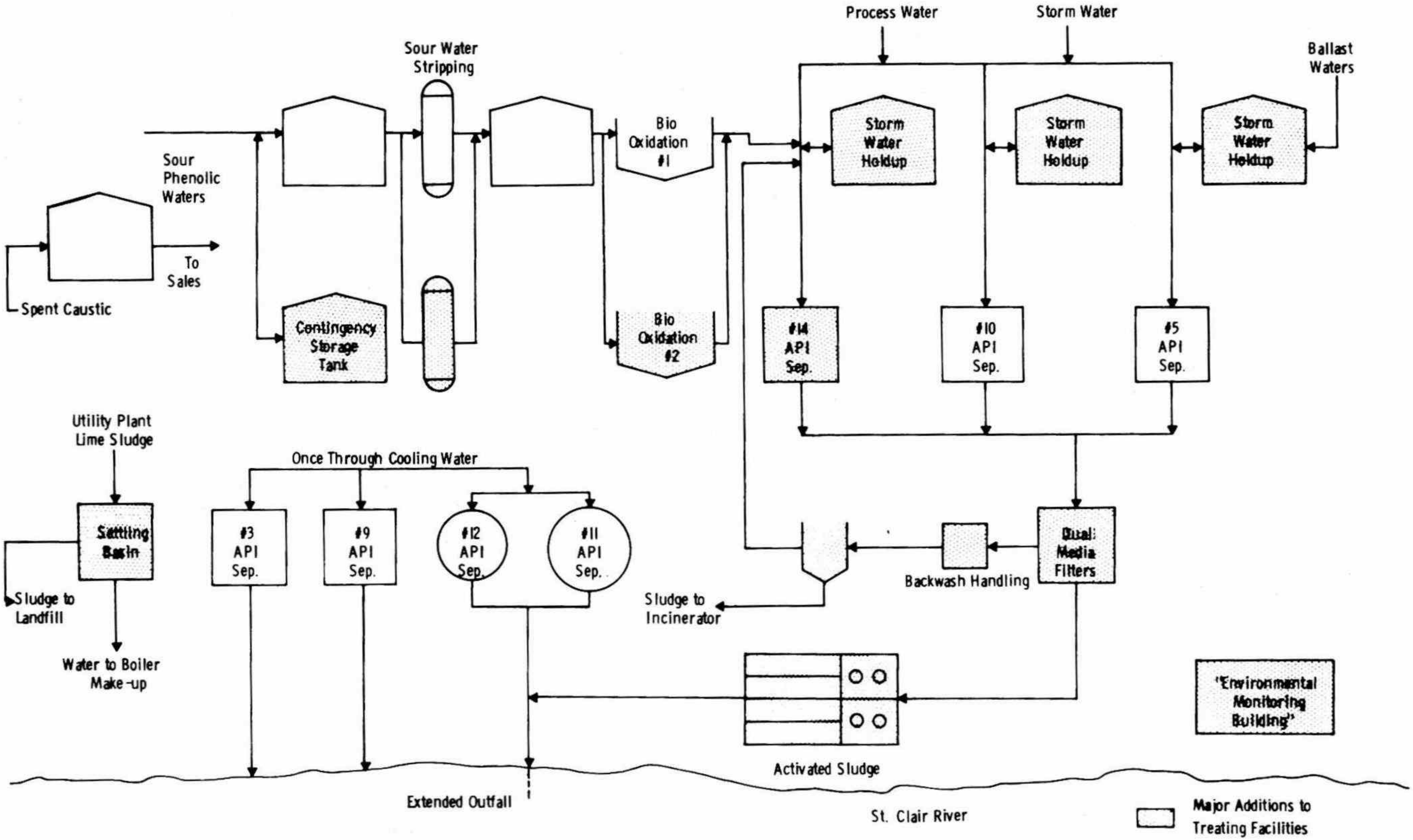
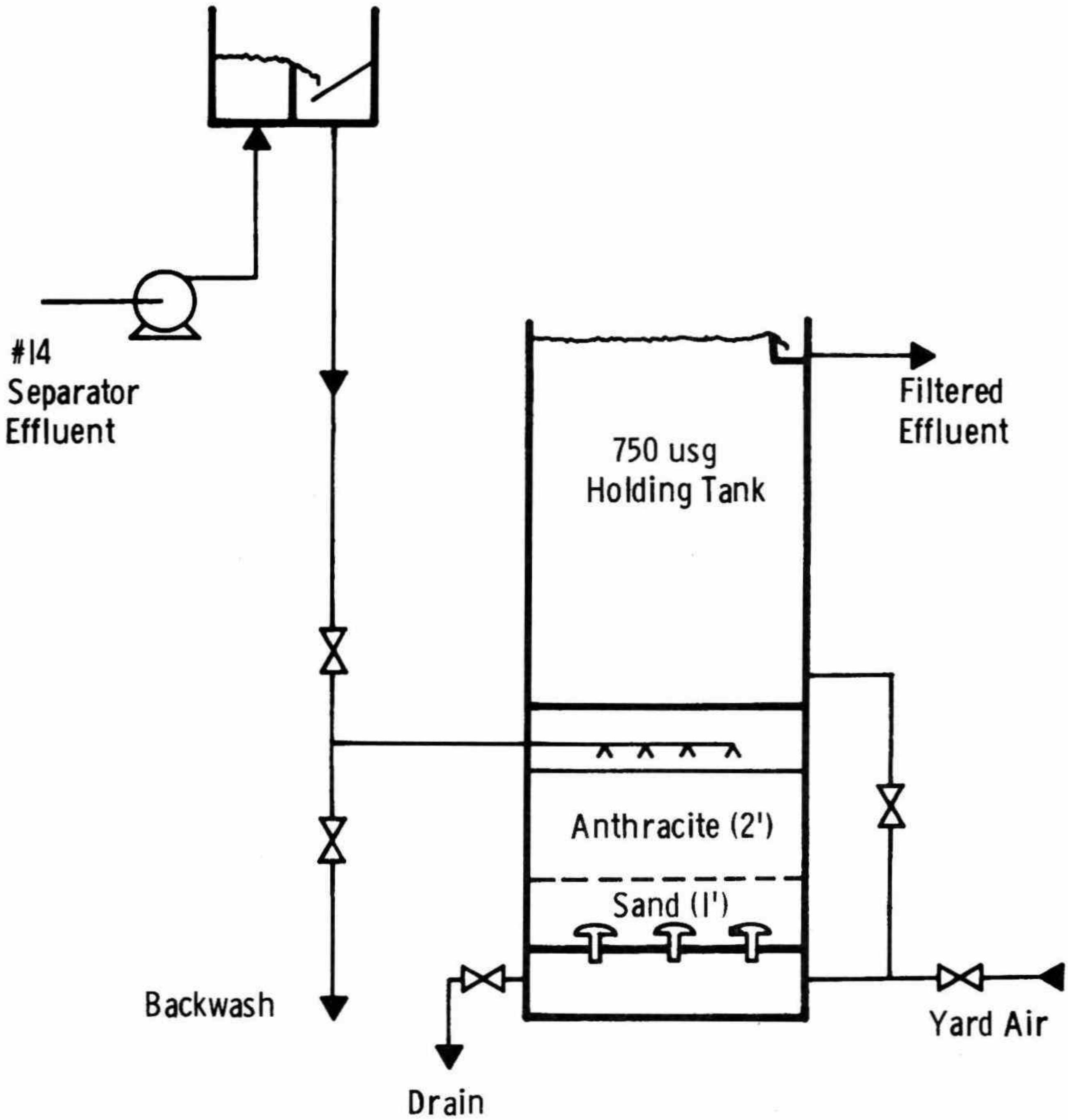


Figure 3

DUAL MEDIA FILTRATION PILOT PLANT (4' Dia.)



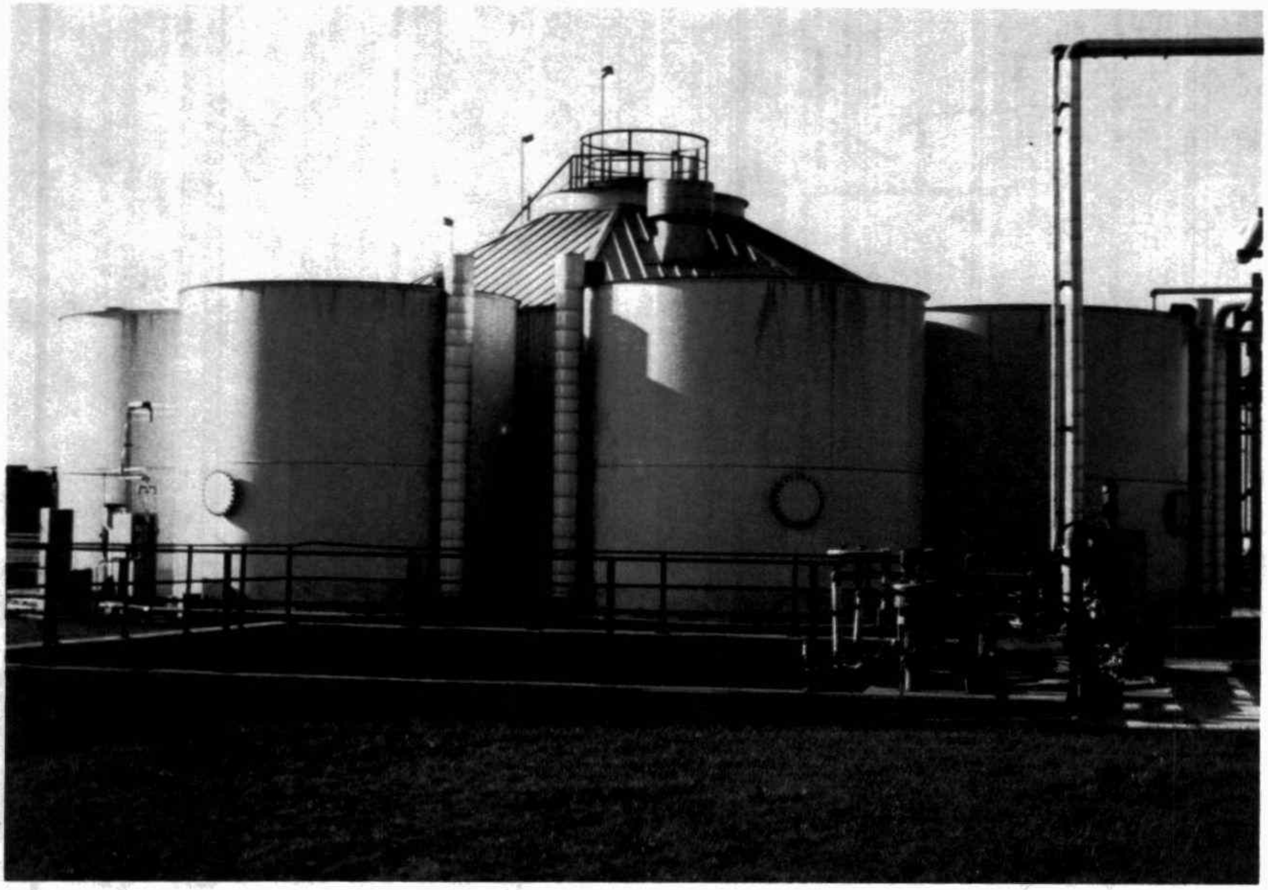
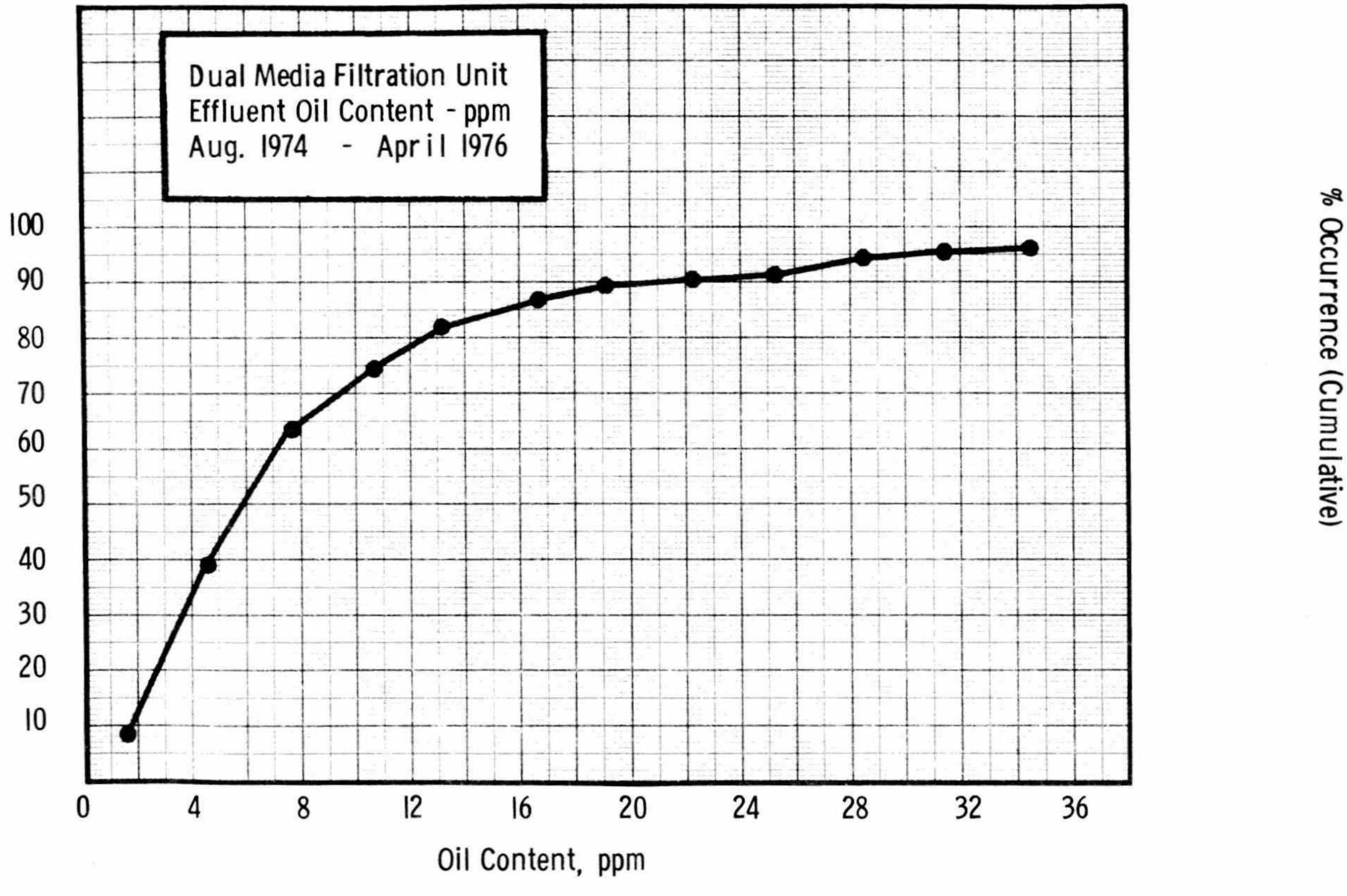


FIGURE 4

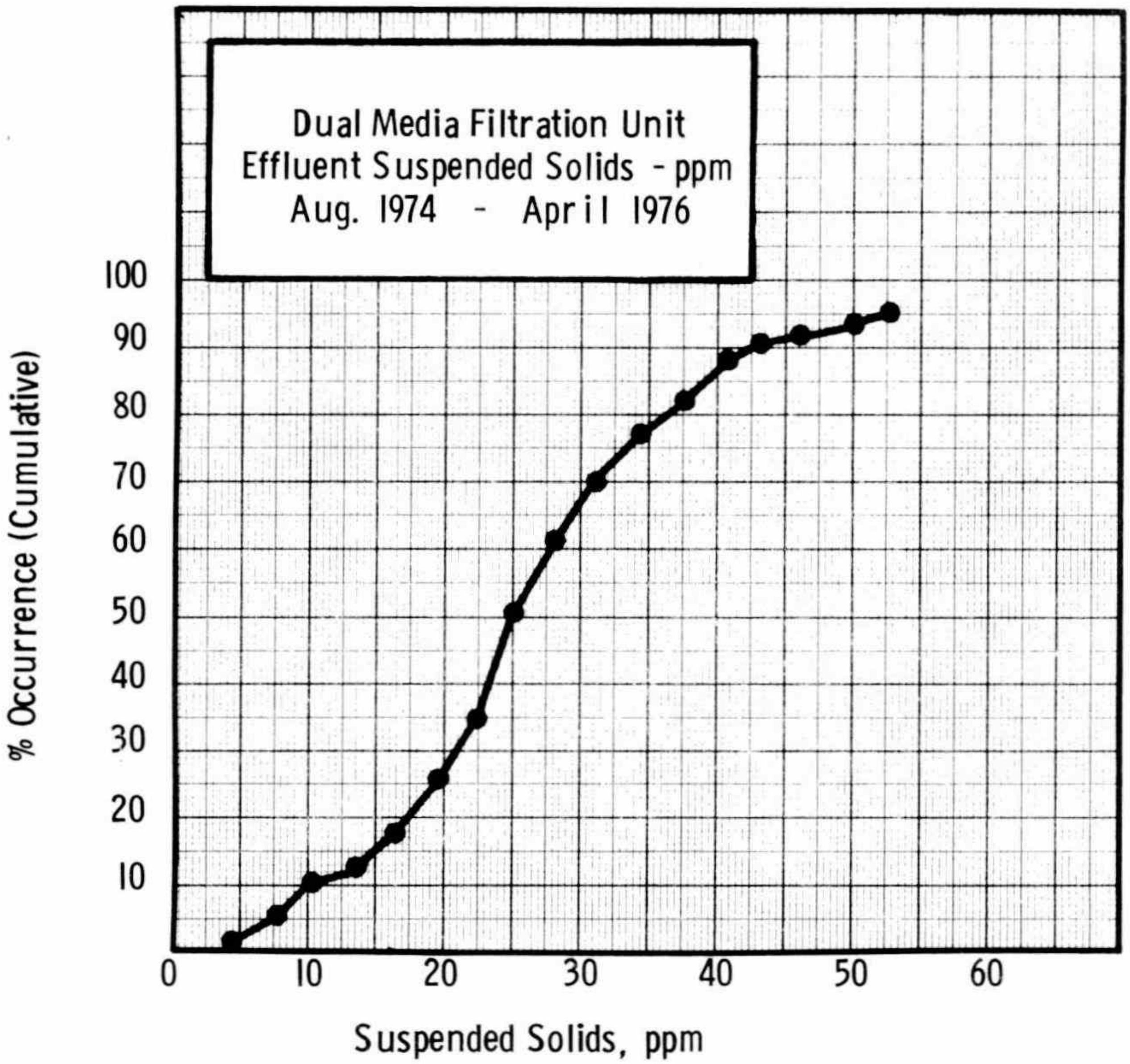
DUAL MEDIA FILTRATION PLANT. BACKWASH HOLDING SUMP IN FOREGROUND.

Figure 5



Dual Media Filtration Unit
Effluent Oil Content - ppm
Aug. 1974 - April 1976
100
90
80
70
60
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
Oil Content, ppm
% Occurrence (Cumulative)

Figure 6



Dual Media Filtration Unit
Effluent Suspended Solids - ppm
Aug. 1974 - April 1976
100
90
80
70
60
50
40
30
20
10
% Occurrence (Cumulative)
0
10
20
30
40
50
60
Suspended Solids, ppm

FIGURE 7

ACTIVATED SLUDGE PLANT. FOUR CLARIFIER BAYS AND SLUDGE RECYCLE SCREW PUMPS IN FOREGROUND. AERATION BASINS IN BACKGROUND.

TABLE 1

ACTIVATED SLUDGE PLANT

DESIGN PARAMETERS FROM THE BIOX PILOT WORK

FLOW RATE, MM usg / day	6
AERATION RESIDENCE TIME (hr)	6
MLSS, (mg/l)	2000 - 2500
% MLSS VOLATILE	80 - 85
ORGANIC LOADING (lb BOD/lb MLSS, day)	0.15 - 0.25
SLUDGE VOLUME INDEX (cc/g)	< 100

TABLE 2

AVERAGE OPERATION OF BIOX PILOT UNIT DURING TEST WITH 6-HR RESIDENCE

	FEED	PRODUCT	% REDUCTION
pH	7.5 - 8.5	6-8	--
BOD, mg/l	81	5 (soluble)	94
TOC, mg/l	41	18 (soluble)	56
OIL, mg/l	6	2	70
PHENOL, mg/l	$\sim$ 0.2	$<$ 0.1	--
SULPHIDE, mg/l	NIL	NIL	--
AMMONIA, mg N/l	8	0.8	90
SUSPENDED SOLIDS, mg/l	17	18	--
TOXIC TO FISH *	YES	NO	--

* 96-hr Static Test

TABLE 3

ACTIVATED SLUDGE PLANT - ACTUAL VS PREDICTED PERFORMANCE

	EFFLUENT QUALITY		% REDUCTION	
	PREDICTED	ACTUAL	PREDICTED	ACTUAL
pH	6-8	6.6-8.7	--	--
BOD - ppm	5 (soluble)	5 (soluble)	94	94
TOC - ppm	18 (soluble)	20 (soluble)	56	62
OIL - ppm	2	9.4	70	24
PHENOL - ppm	$<$ 0.1	0.026	--	96
SULPHIDE - ppm	NIL	NIL	--	--
AMMONIA - ppm	0.8	10.6	90	8.5
SUSPENDED SOLIDS - ppm	18	39 ‡	+	+
FISH TOXICITY TEST	PASS *	PASS **		

* 96 hr. static tests

** 24 hr. static tests

‡ Improvements Underway

TABLE 4

REFINERY EFFLUENT QUALITY VS FEDERAL AND PROVINCIAL GUIDELINES

PARAMETER	ONTARIO GUIDELINE (ppm)	REFINERY EFFLUENT (ppm)		FEDERAL GUIDELINE (lbs/1000 Bbls)	REFINERY DISCHARGE (lbs/1000 Bbls)
		ACT. SLUDGE EFFLUENT	DISCHARGE TO RIVER		
PHENOL	0.02	0.026	0.005	0.6	0.008
OIL	15	9.4	1.8	6.0	3.0
SUSPENDED SOLIDS	15	39	7.2	14.4	11.8
AMMONIA	10	10.6	1.9	5.0	3.1
SULPHIDES		--	--	0.2	--
pH	5.5 - 9.5	6.6 - 8.7		6.0 - 9.5	6.6 - 8.7
FISH BIO-ASSAY *				PASS	PASS

* 24-hr. Static Test

POLLUTION ABATEMENT AT CANADA STARCH

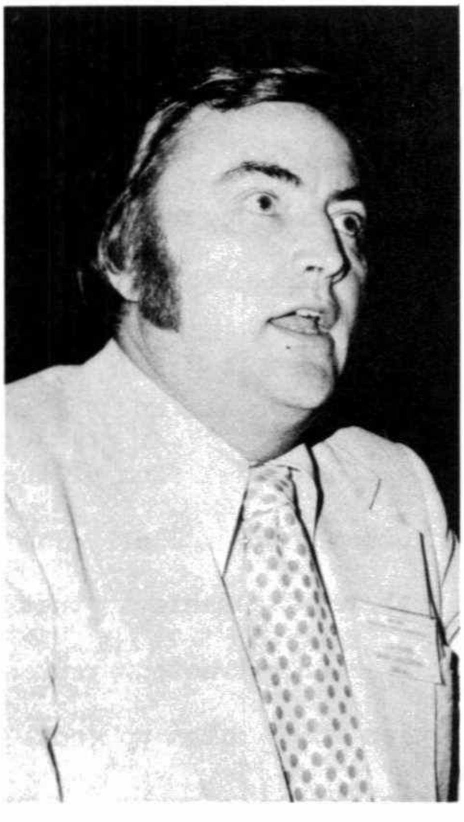
A CASE STUDY

The pollution problems associated with the operation of a corn wet milling plant are outlined. The effluent streams were segregated into those usually acceptable for discharge to the St. Lawrence River and into a single stream with BOD readings of up to 3000 ppm. The acceptable streams are continuously monitored with Technicon Monitor IV's together with an alarm system to initiate corrective actions fifteen minutes after the first occurrence of an upset. After careful consideration of several biological treatment systems, a single cell aerobic facultative or aerated lagoon was chosen. The lagoon was constructed by converting an old sumberged canal in the St. Lawrence Seaway into a waste treatment plant having approximately thirty days retention time and which has operated with an 85-90 per cent reduction of BOD during the summer months and 60-75 per cent during the winter months. The total program is responsible for an overall 85-90 per cent reduction in BOD to the St. Lawrence River.

by

GERRY N. FULFORD

Technical Superintendent,
The Canada Starch Company Limited
Cardinal, Ontario



Mr. Fulford, born and raised in Windsor, Ontario, graduated from Queens University with a degree in applied science, specializing in chemical engineering. He was employed by C.I.L. as an industrial engineer concerned with process cost analysis. He spent three years as Research Officer with the Federal Department of Mines and Technical Surveys on various projects associated with the Athabasca tar sands, including high pressure hydrogenation studies and catalyst research on the resulting distillates. For the past twelve years he has worked for The Canada Starch Company Limited, Cardinal, and in his present position, since 1974, is responsible for quality assurance, process engineering and pollution abatement programs.

POLLUTION ABATEMENT AT CANADA STARCH
A CASE STUDY

by

GERRY N. FULFORD

The company which I represent is one of several companies throughout Canada involved in the production of starch and sweeteners from corn. As a member of the corn wet milling industry, the Canada Starch Company is actively committed in the fight against water pollution. From its beginning positive steps have been made to increase the efficiency of the plant and decrease the loss of material and chemicals to the river.

Each year the Canada Starch Company processes in the neighbourhood of 7 million bushels of corn. For each bushel of corn processed 6 to 12 gallons of water are used in direct contact with the corn or its components. An additional 200 - 350 gallons/bushel ground may be used for cooling water, steam and power generation. Because of the large volumes of water used, the wet milling industry has a vital interest in maintaining the quality of the water.

Wet Milling Industry:

So that you may understand the nature of the problems faced by the corn wet miller, a brief introduction to our industry may be helpful.

The use of corn was reported before North America was discovered by Columbus. It is known that the Stone Age man used it as food. The Indians in North America worshipped it. Christopher Columbus, on return from North America, brought corn instead of gold which greatly upset Queen Isabella. It also played an important role in the life style of the pilgrims.

There are four basic components in a kernel of corn; the hull, the germ, the gluten and the starch. The hull or bran is the tough outer skin of the kernel. It consists primarily of fibers and is of little value to the miller. The germ which is located in the center of the kernel is extremely valuable in that it contains 95% of the oil available in the corn which, when extracted, represents a very viable commercial product. The gluten portion which makes up about 10% of the kernel is found bound together with the starch and when separated contains

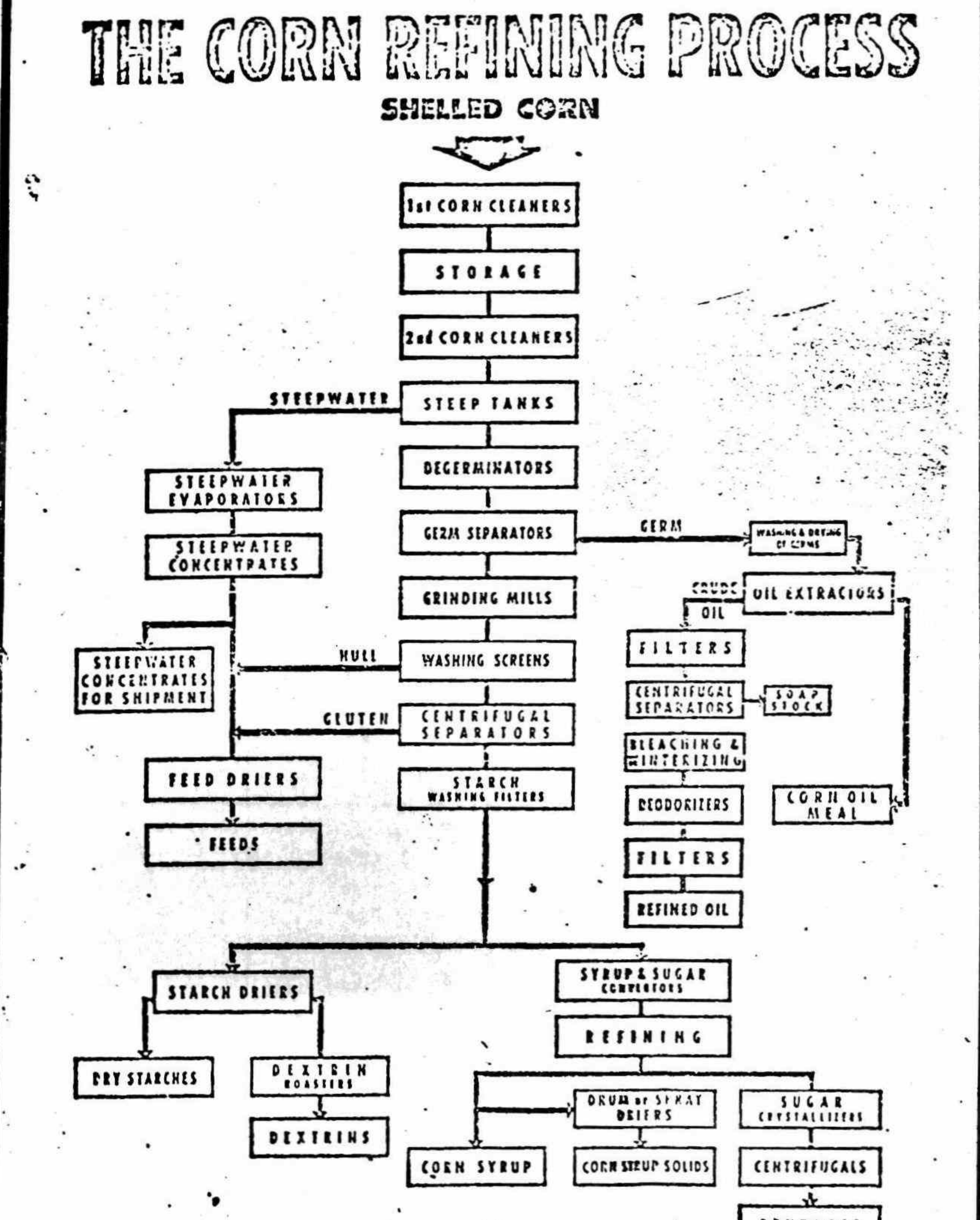

THE CORN REFINING PROCESS
SHELLED CORN
1st CORN CLEANERS
STORAGE
2nd CORN CLEANERS
STEEPWATER
STEEP TANKS
DEGERMINATORS
STEEPWATER EVAPORATORS
GERM SEPARATORS
GERM
WASHING & DRYING OF GERMS
STEEPWATER CONCENTRATES
CRUDE OIL
OIL EXTRACTORS
GRINDING MILLS
STEEPWATER CONCENTRATES FOR SHIPMENT
HULL
WASHING SCREENS
FILTERS
CENTRIFUGAL SEPARATORS
SOAP STOCK
GLUTEN
CENTRIFUGAL SEPARATORS
BLEACHING & WINTERIZING
FEED DRIERS
STARCH WASHING FILTERS
DEODORIZERS
CORN OIL MEAL
FEEDS
FILTERS
REFINED OIL
STARCH DRIERS
SYRUP & SUGAR CONVERTORS
REFINING
DRY STARCHES
DEXTRIN ROASTERS
DEXTRINS
DRUM or SPRAY DRIERS
SUGAR CRYSTALLIZERS
CORN SYRUP
CORN SYRUP SOLIDS
CENTRIFUGALS
DEXTROSE

FIGURE 1

a very high percentage of protein. Finally there is the corn starch which makes up 65% of the kernel. It is the wet milling process that separates the kernel into its component parts.

In the corn milling process, (Figure 1) clean shelled corn is steeped in warm sulfurous acid and the steepwater containing the solubles leached from the corn is drawn off and evaporated. These evaporated solubles, containing a high percentage of nutrients and soluble proteins are added to the feed streams. The softened kernel is then passed through degerminators where the germ is loosened from the kernel; because of its oil content it is separated from the rest of the kernel in hydroclones by a differential in specific gravity and subsequently washed and dried. The dried germ is then processed to recover the crude oil which in turn is refined. The germ free kernel is milled and passed over washing screens to separate the hull from the mill starch which is made up of starch and gluten. The hulls are dewatered, dried and sold as a feed product. The mill starch is separated in centrifugal separators into starch and gluten (protein). The gluten is dewatered, dried and sold as 60 percent protein feed. The starch is passed through a series of counter current washing hydroclones where the last traces of protein and solubles are removed. It is at this point that all the water used in direct contact with the kernel is added. These waters are recycled many times through the process until they eventually end up in the steepwater originally drawn from the steeped corn and evaporated (hence the term "bottled up"). The starch in slurry form may go in one of several directions. It can be dried in its present state, acid modified, oxidized, crossbonded, etc. and then sold to the food and non-food industries depending upon the customer's needs. The starch may also be used as a raw material for the production of corn sweeteners.

The industry has always prided itself on the use of a bottled up process. A decade ago, a bottled up process meant one where the water was introduced only at the final wahing of the finished prime starch, and was worked back into the process whenever it was felt possible. Some of the wash waters in modified starches were impossible to re-use due to their contamination - as a result the plants could be subjected to high losses. Let us review some of the potential hazard areas in the process from a pollution standpoint.

Pollution Hazard Areas in Wet Milling:

Losses incurred from the concentration of the corn steep liquor by evaporators are caused both by entrainment of product and by the condensing of volatile materials. Steepwater evaporators are operated under a vacuum which is achieved by the use of barometric condensers. Depending upon the age of the light steepwater and the condition of the evaporator heating surfaces, the liquor may have a strong tendency to foam. The problem is further complicated by the presence of all the corn soluble proteins. When the foaming occurs, large entrainment losses from the separator bodies result as the slug or shot is carried out in the downlegs of the condensers to the sewers. Few, if any, steepwater evaporators have the luxury of a surface condenser. In addition to the normal operating losses, there are chemical losses from the more volatile materials such as alcohol and organic acids which are distilled over the top of the evaporator and condensed in the steam chests. These volatile losses will always be present but may be controlled by reducing the lag times in the process and carefully controlling the steeps. Greenfield et al (1) described the use of steam stripping to remove the volatiles from the steepwater prior to concentrating. From past plant experiences, losses from the steepwater pans could range from 0.07 - 0.10 lb. BOD/bushel with approximately 0.02 lb./bushel being made up of volatile distillates in the condensates. With the use of surface condensers,

these loss figures can be reduced, from a pollution standpoint, as they are present in a more treatable volume.

The washing and drying of corn starch to a pearl or powdered form does not represent a pollution hazard itself. Starch, as you know, when cooked in water results in a cloudy non-cohesive solution, and upon cooling has a tendency to paste or "set" up into a gel. While this property is useful in some areas such as paper sizes, brewers grits, laundry starches and some food and canning applications, it is highly undesirable in others. The viscosity and "gel" characteristics may be greatly altered through chemical treatment or modification of the starch. This chemical modification of the starches breaks down the starch molecule into hydrolyzed fragments thereby altering the physical characteristics of the starch. In the course of the conversion some of the starch is solubilized. This soluble starch and the residual chemicals from the conversion are washed from the starch prior to drying. In most treatments, these wastes cannot be readily recycled back to the process and represent a major pollution hazard. As a rule of thumb, we might say the greater the degree of chemical modification the greater the resulting waste treatment load.

TABLE 1

Approximate Waste Treatment Loadings
For Various Classes of Starch

(0.17 lbs. BOD/Population Equivalent assumed in calculations)

	Lb. BOD/Bu.*	Population Equivalent/Bu.
Prime Starch, Pearl or Powdered	0	0
Bleached Starch	0 - 0.1	0 - 0.6
Acid Modified	0.25 - 0.60	1.5 - 3.5
Crossbonded, acetylated etc.	0.75 - 2.5	4.4 - 14.7
Oxidized Starch	2.25 - 3.00	13.2 - 17.6

*Based on 0.82 lbs. BOD/lb. Starch

In many cases, the solubles cannot be evaporated and added to feed due to the toxic nature of the chemicals used. While these figures would vary due to differing processes and actual product mix being run, they do indicate the severity of the treatment problems that can arise in producing modified starches.

Corn starch is a polymer or chain of dextrose units, less a water molecule. To produce corn sweeteners, a hydrolysis or breakdown of these chains is carried out yielding components varying from single dextrose molecules to long chain polymers. The hydrolysis of the starch may be carried out by three methods: (1) acid, (2) acid-enzyme or (3) enzyme-enzyme processing. The acid enzyme process is the most widely used in North America today. The starch slurry is initially treated with acid and heat for a period of time, neutralized, cooled and treated with enzyme that will selectively break down the starch polymer. When the hydrolyzate reaches the required dextrose level, it is clarified to remove trace quantities of naturally occurring fatty substances and proteins that were present in the prime starch. It is then decolorized with carbon and evaporated to the desired concentration. These evaporators are subjected to entrainment losses. However, the hydrolyzate does not have the same tendency to foam as steepwater. With good evaporator design, process operation and monitoring, these losses can be greatly reduced. Losses can occur from the sweetening off of spent carbons, regeneration of ion exchange columns, leaks from pump seals and heat exchangers. Tank car washings and sterilization can result in very large losses to the sewers if not carefully controlled. Greenfield has reported the BOD losses over a period of time from a typical plant as 0.23 population equivalent (PE) from entrainment, 0.27 from spills and 0.71 from washing for a total of 1.21 P.E. per bushel per day of refinery grind allotted to the syrup and sugar refineries.

All processing plants are subject to upsets and imbalances through equipment breakdowns, instrument failure, operator errors, leaks etc. which result in product and material being lost to the floors. As the processing is carried out in the slurry form, these spills must be washed up. If these wastes are washed to sewer they can severly pollute the water courses or if they are treated can represent a shock loading to the waste treatment facilities.

To put the waste treatment problem into perspective, a small corn wet milling plant would be faced with the same treatment problem as a city with a population of 175,000.

Categorizing Wastes - Volume and Strength

In 1964, the Canada Starch Company was operating what it considered to be a well executed "bottled-up" process (2). The waste loadings discharging to the sewer were 1.0 lbs. BOD and 0.53 lbs. of suspended solids per bushel of corn processed. The treatment was due to a large dilution factor and the assimilative capacity of the river to handle the waste.

Repeated surveys indicated the waste was completely assimilated by the St. Lawrence Waterway 75 feet from the Company outfalls.

However, we were soon to learn that dilution was not a solution and a waste treatment facility would be required. It is axiomatic to say that before a waste treatment plant can be considered, it is necessary to have some reasonable knowledge of the volume and strength of the wastes to be treated. Complicating the problem was the fact that the plant was established over 100 years before and had developed somewhat randomly to meet the growing production demands. As in most older plants of this nature, the sewer systems were complicated and somewhat irrational, containing many branches which had not been charted. It was impossible to define distinct networks which separated dike seepage and storm water from industrial wastes and sanitary sewage. In the fall of 1965, the services of Proctor and Redfern were engaged to investigate the sewer system as well as the strength and nature of the waste.

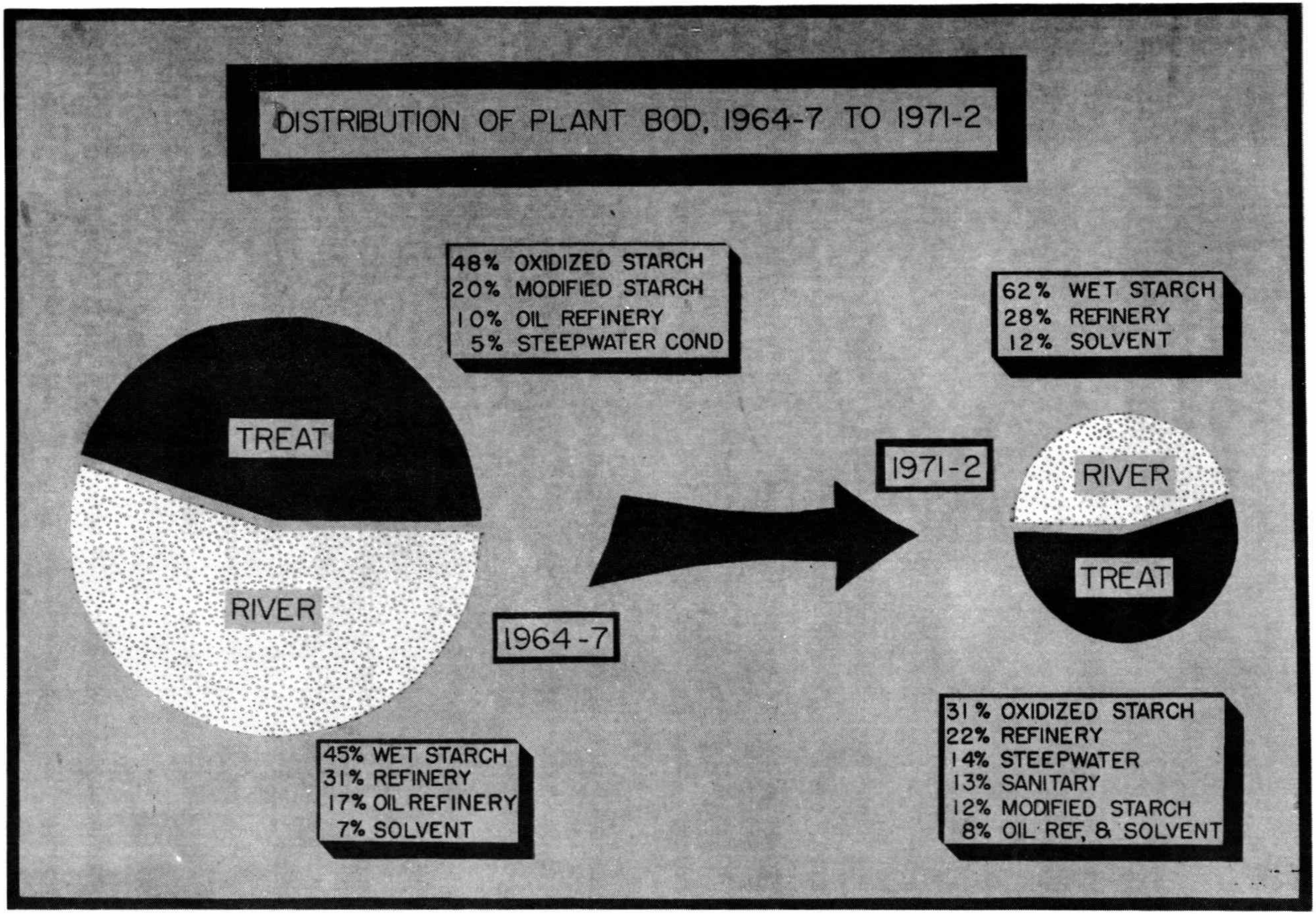


Figure 2 Distribution of plant BOD, 1964-7 to 1971-2. Overall reduction represented a change in loading from 1 lb. BOD/Bu. to 0.21 lbs. BOD/Bu.

As a basis for the study, agreement was reached with the O.W.R.C. to categorize the wastes into three classes, namely;

(a) Wastes of very low strength that could be discharged directly to the St. Lawrence River without treatment.

(b) Those medium strength wastes that could be treated by some simple physical process and then discharged to the river.

(c) The very strong wastes which required complete biological treatment to meet a standard suitable for discharge to the St. Lawrence River.

The study revealed that the sewer system did indeed need revamping and recommended the establishment of three distinct sewer networks, namely a sanitary sewer, industrial waste sewer and a storm sewer system. By quantitative determinations, the actual losses from the various departments and products were established for the first time. They were grouped initially into two categories; those that should be collected together and treated and those that normally would be acceptable for discharge to the River. Forty-five percent of the total BOD was considered high strength and designated for treatment. The oxidized starches made up 48 percent of this loading, 20 percent the modified starches, 10 percent the oil refinery, (Figure 2).

The oxidized starches were almost exclusively sold to the fine paper manufacturers and they too were experiencing water problems in using these. Gillespie (3) reports that the dispersive action of the hypochlorite oxidized starches was decreasing the filler retention and increasing the white water turbidity. Excessive turbidity rendered the white water unfit for direct re-use. As a result, the fresh water use was increased, and the volume of difficult-to-treat effluent was increased. Through the late sixties to early seventies, both industries were actively seeking alternate products that would be an acceptable substitute for the oxidized starches. Ethylated and cationic starches were used with some success. The combination of reduced use of oxidized starch and numerous

trials with the substitute starches had a distinct effect of reducing the treatment load. Now the product is obsolete and has been replaced by enzyme conversion of normal prime starch.

Many of the modified starches met the same fate. Each starch processor and user carefully reassessed the economic return from the product or its use against the added waste treatment costs.

The other main contributor to the treatment load was the oil refinery. Here the crude oil is treated with caustic to remove the free fatty acids in the form of soap, bleached to yield a light coloured oil for marketing, winterized to remove the natural waxes that could cause haze upon refrigeration and filtered to improve the clarity. Finally the oil is deoderized to remove any odoriferous and volatile ingredients, thus improving the shelf life and imparting the familiar bland "Mazola" corn oil flavour. The deodorization is accomplished by steam stripping under high temperature and reduced pressure. The volatile materials distill off and condense or solidify in barometric downleg waters presenting an unpleasant waste treatment problem. An Elliott Scrubber, using a curtain of recycled corn oil was installed before the condensers to strip out the volatile distillates. Periodically the recovered distillate is drawn off and sold with the soapstock.

Tighter re-use of process waters, improved level controllers on the plant evaporators, a revamped sewer system and the appointment of a full time yield and loss foreman all played a large part in reducing the untreated wastes as shown in Figure 2. The plant losses were reduced to approximately 0.21 lb. BOD/bushel with 0.12 lb. BOD/bushel in the industrial sewer designated for further treatment.

When the process and sewer changes had been completed, permission was granted by the O.W.R.C. to return 93 percent of the water used by the plant directly to the river. To reduce the potential of any waste inadvertently finding its way to the river, and elaborate monitoring system was to be established. The remaining 7 percent of the water contained 51 percent of the BOD loading.

Lagoon Design & Construction:

The design of the treatment facility was not straightforward. The nature of the waste, production cycles, volume and strengths all added to the dilemma. and have been outlined below:

1. A large percentage of the waste was from the hypochlorite oxidized starches. These wastes did not respond to biological treatment as quickly as the normal starch wastes. They could also contain a large amount of free chloride. Little BOD reduction was realized in the first few hours.
2. Production mix was such that the characteristics of waste could change markedly from day to day or week by week introducing acclimatization problems for any type of waste treatment facility.
3. Treatment loadings were frequently the result of process upset. The treatment system would be subjected to shock loadings of up to 3000-4000 ppm BOD.
4. The grind schedule often called for plant shutdowns of up to four days duration making the operation of an activated sludge plant extremely unstable.
5. The volume of liquor treated was extremely large. Equalization could be considered for the short periods during a "shock loading" situation, but for any production runs of highly modified starches the storage facility would have to be so large that they would neither be economical nor aseptic.

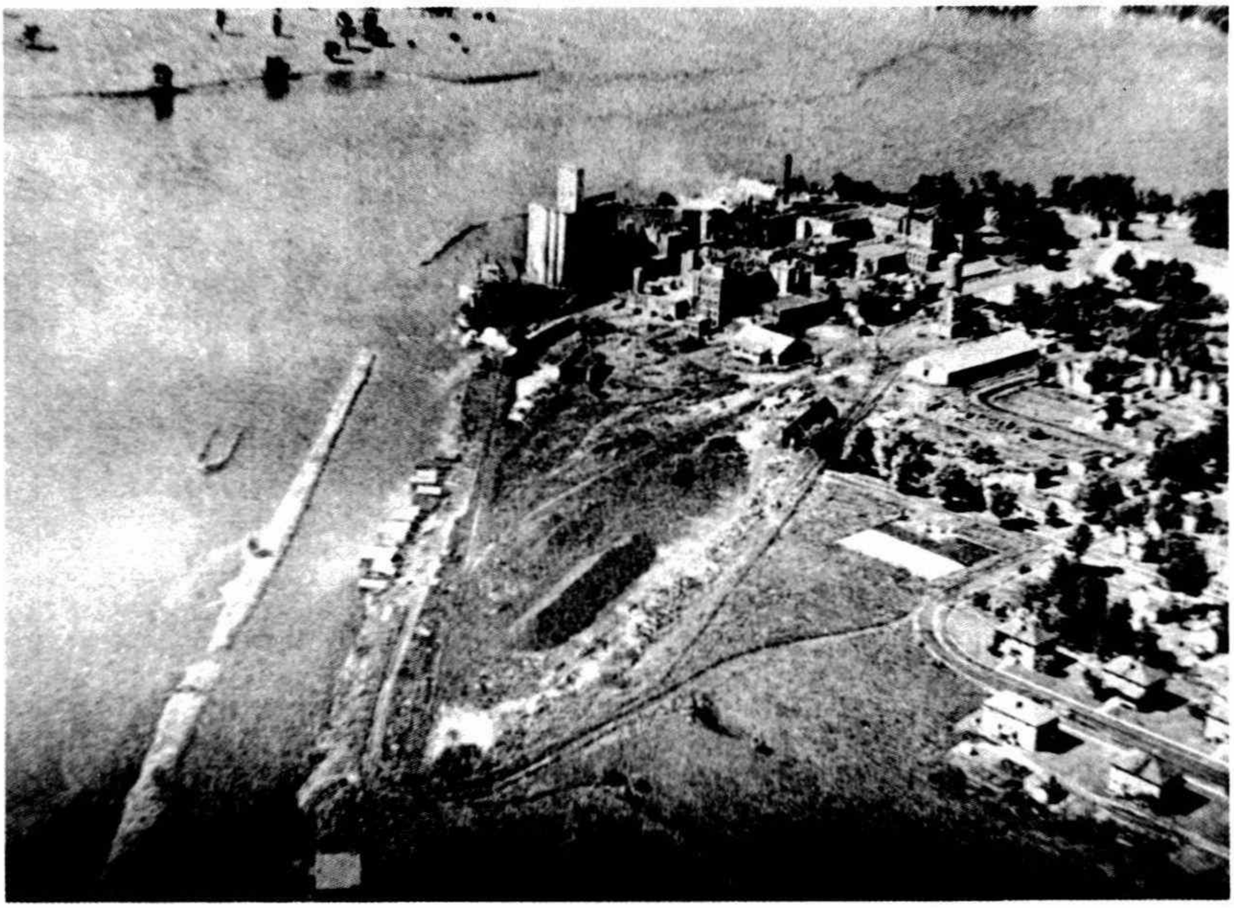


Photo 1 Aerial view of St. Lawrence River showing Gallop Canal prior to its flooding in 1956

Photo 2 Aerial view of earthen berm constructed as the outer wall of the aerated lagoon

Early work had suggested that aerobic facultative lagoons may well answer many of the above needs. Experience with these earlier lagoons, described by Sawyer (4), suggested the use of 20 lb. BOD/1000 ft.^{3} and the lagoons generally used a 1.2-1.5 lbs. O_2/lb. BOD. However, Boyko (5) of the O.W.R.C. gave a paper at this same conference in 1971 suggesting that a design loading of 2 lbs. BOD/1000 ft.^{3} had met with success in Ontario and should give an effluent of acceptable quality. The loading restraint, coupled with the potentially high strength and volume of the effluent suggested that a very large treatment facility would be required. This posed an additional problem as there was no open land available close to the plant site. The increased capital and operating costs that would be incurred by pumping the waste to a suitable open site were economically prohibitive.

There was one other alternative for the Company and consulting engineers: that of using a portion of an old canal system. In the mid 1800's, the Gallop canal system had been constructed to improve the river navigation in the St. Lawrence near what is now Cardinal. The corn grinding mill was erected on the canal's north bank where it could take advantage of the head water. Unused for many years, its banks badly erroded, the canal was flooded in 1956 by the construction of the St. Lawrence Seaway leaving only a submerged hazard to navigation.

To establish the feasibility of utilizing the existing berms of the old canal, the services of Warnock Hersey Company were engaged to test the conditions of the subsoil. These tests confirmed that the bank of the old canal would serve as a suitable foundation for the outer perimeter of an earthen berm.

Photo 3 Aerial view showing dredging operation in fall of 1972

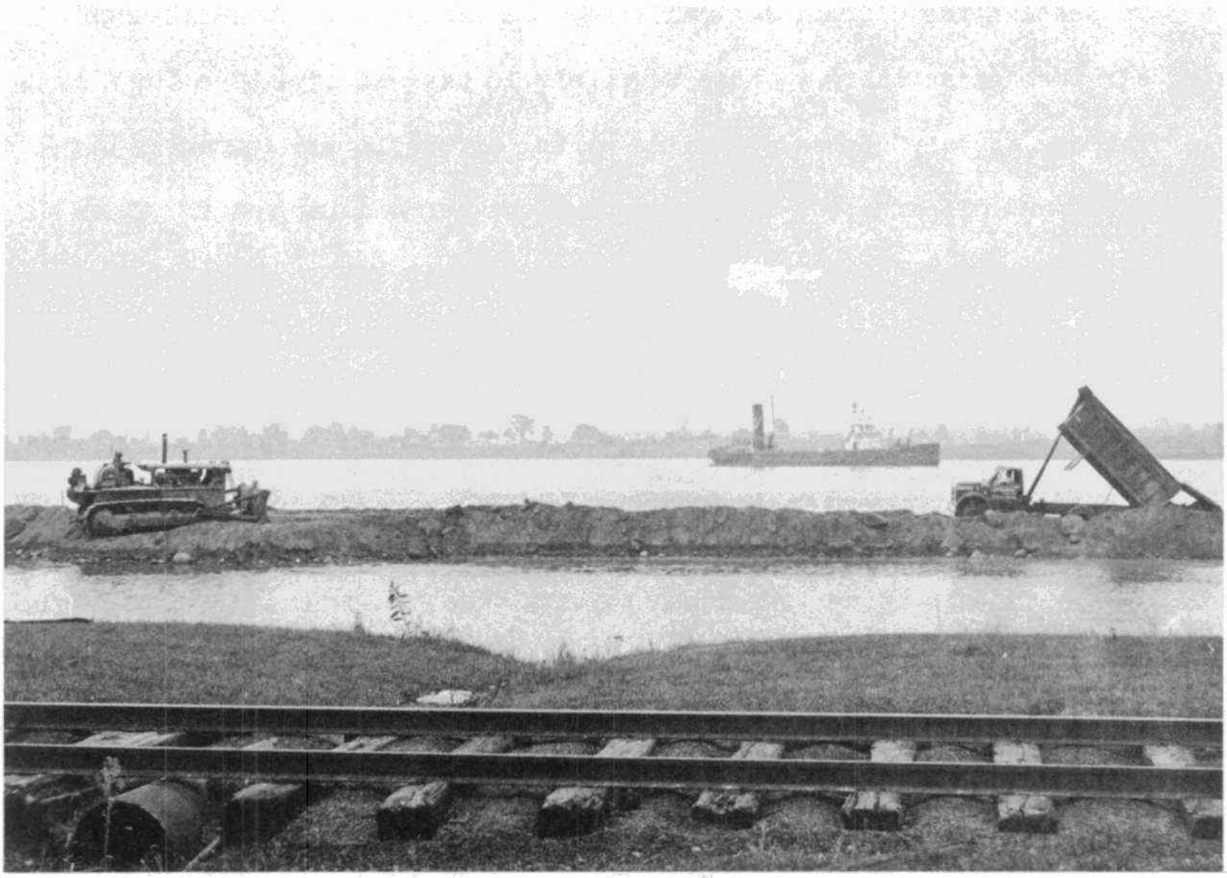


Photo 4 Shows the end dumping of a specially selected glacial till used to create the impervious outer berm of the lagoon

The design of the lagoon was carried out by the Proctor and Redfern Group (6). To meet the design loading requirements of the Ministry, an aerated lagoon was constructed, approximately 1000 feet long, 135 feet wide (inside) and 20 feet deep having a liquid volume of 12.5 million gallons and a surface area of 2.8 acres. The walls of the berm were constructed by end dumping from trucks, a specially selected glacial till which was well graded in particle size. The use of similar tills had been described previously by Adams (7) of the Hydro Electric Power Commission of Ontario. The compacted till formed a dense, impervious layer making it possible to maintain a constant level in the lagoon irregardless of the river level. To protect the berms from the wave action of passing ships and from the turbulence created by the mechanical aerators, the exposed faces were covered with a rip-rap made of a crushed stone underlayer followed by a primary cover of heavy quarry-run rock. The lagoon bottom was dredged to a specified contour.

To sustain the microbiological life, the air is introduced through applied air turbine aerators. These were felt to have an advantage for this type of lagoon, as they not only provide mixing of the lagoon contents, but they break up and disperse the air throughout the surrounding water. There is no surface spray experienced, thereby reducing some of the problems of winter icing and foaming. It was assumed that the aerators would be sized for the oxygen required for an Alpha factor of 0.8, a Beta factor of 0.8 and a residual dissolved oxygen level of 2.0 mg/l. Five Lightning submerged turbine aerators were used with 150 installed HP. In these units, the drive shaft to the turbine is hollow with the air being introduced through this hollow shaft. The air is supplied to the turbines by five rotor positive type, belt driven compressors using 110 installed HP. To reduce the normal noiselevel for the nearby residents of the Village, the compressors were enclosed in an accoustical lined metal cabinet.

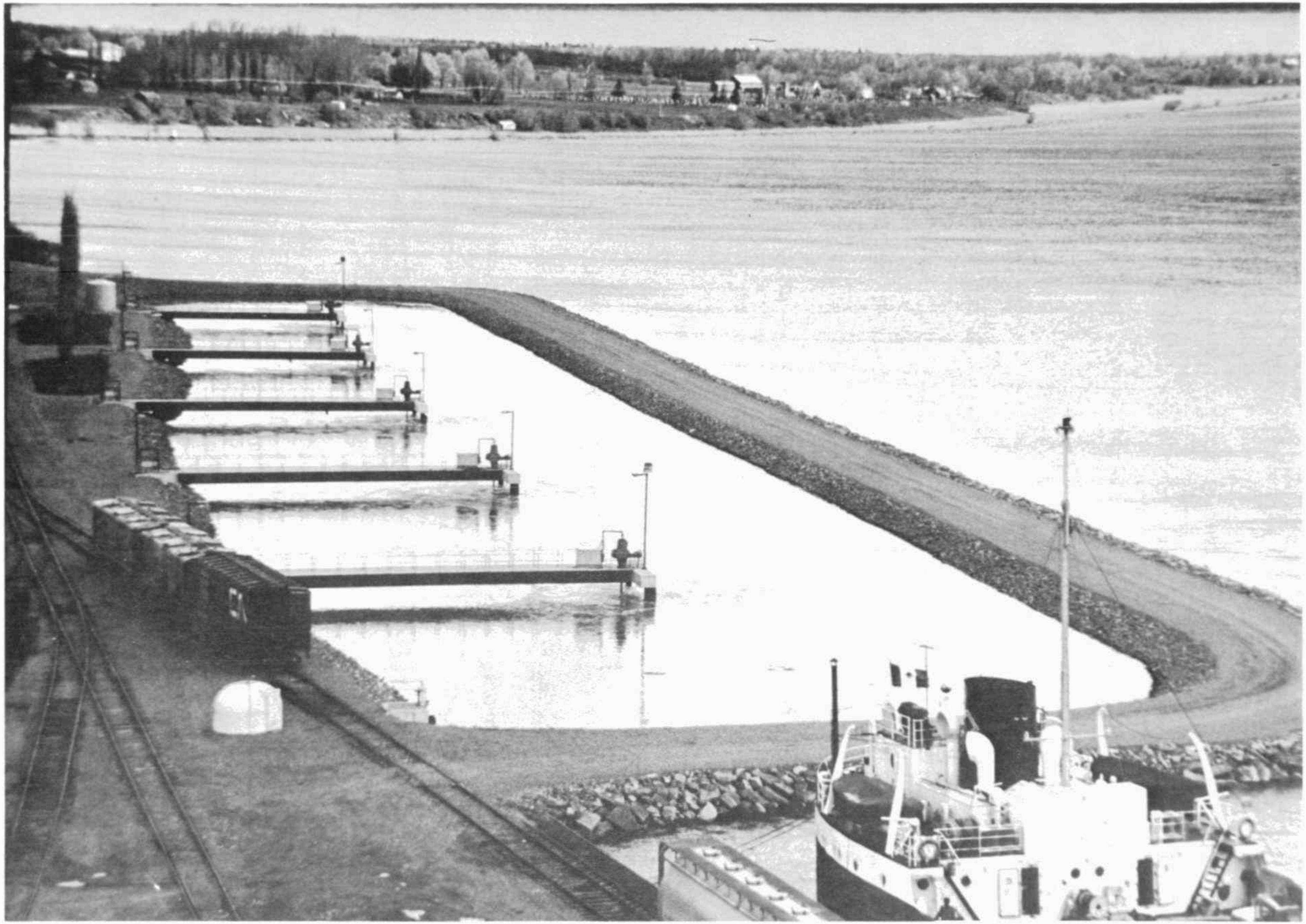


Photo 5 Aerial view of the faculative aerated lagoon used for waste treatment at Canada Starch since 1973

As the lagoon could not be dewatered during its construction, it was decided that the fixed operating platforms for the aerators could be established by driving raked steel tube piles from a barge through the boulder clay overburden to refusal. Baffles for the aerator were provided by welding steel plate to the piles prior to driving. The corner pieces were suitably braced by a rigid precase concrete cap. The frames were stiffened in the weak direction by 80 foot long prestressed concrete tees that also served as the access platform. At the discharge end of the lagoon a 100 ft. arc of perforated pipe chlorinates the waste prior to its discharge. The effluent flows through a discharge weir and then through 350 feet of sewer to a submerged discharge.

The contract for the lagoon construction was awarded to Ruliff Grass Limited and was completed in early 1973.

Lagoon Operation:

The concept of using a single cell aerated or facultative lagoon for high strength industrial wastes is not new. Rice and Weston (8) were among the earlier workers to report the use of compressed air to overcome the stratification and the development of undesirable anaerobic conditions in waste treatment ponds. In 1966 O'Connors and Eckenfelder (9) presented a comprehensive paper describing their laboratory work, field results and design criteria for aerated lagoons. Since the early "Sixties", the use of a facultative lagoon to handle high strength organic wastes has been generally accepted where the land is available.

A simple aerated lagoon, unlike the more conventional activated sludge plants measures retention time in days or weeks rather than hours. The concentration of the mixed liquor solids developed within the aerated waste does not normally exceed 100 ppm and generally is uniform throughout the basin.

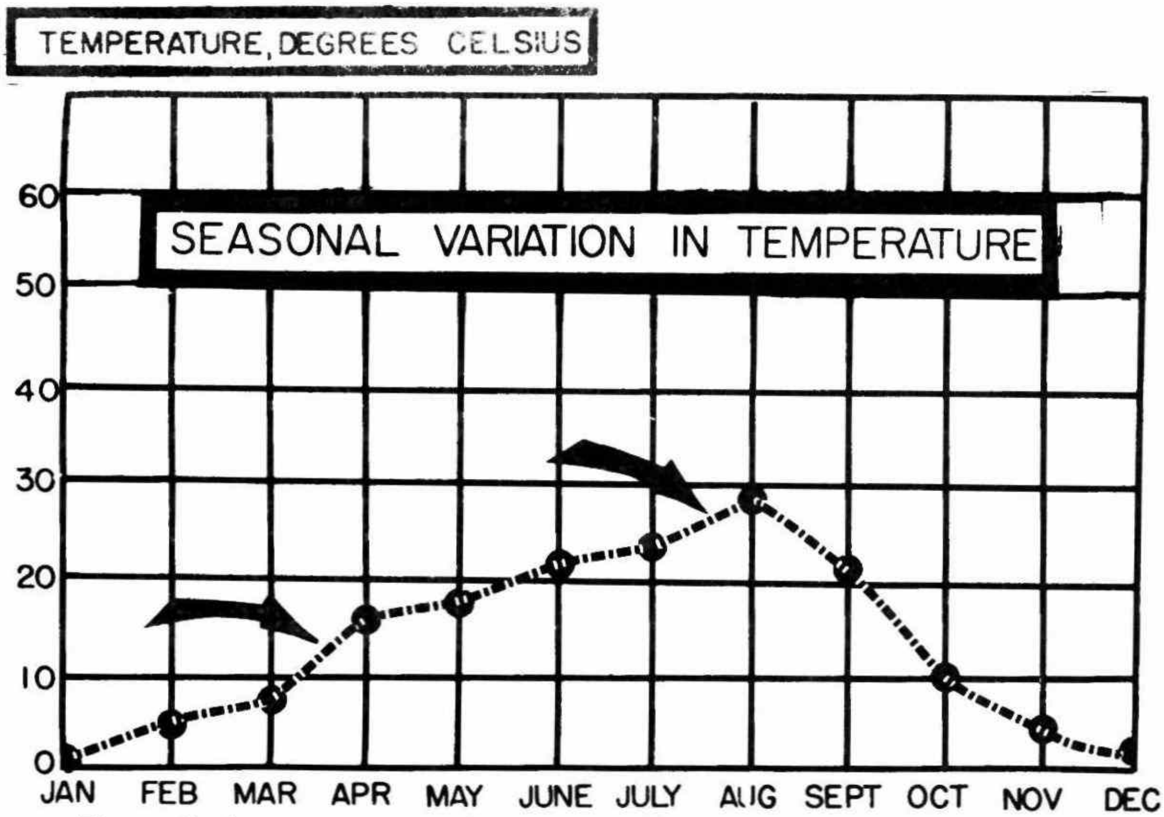


Figure 3 Average seasonal variation of lagoon operating temperature. Arrows indicate critical temperatures for lagoon stability.

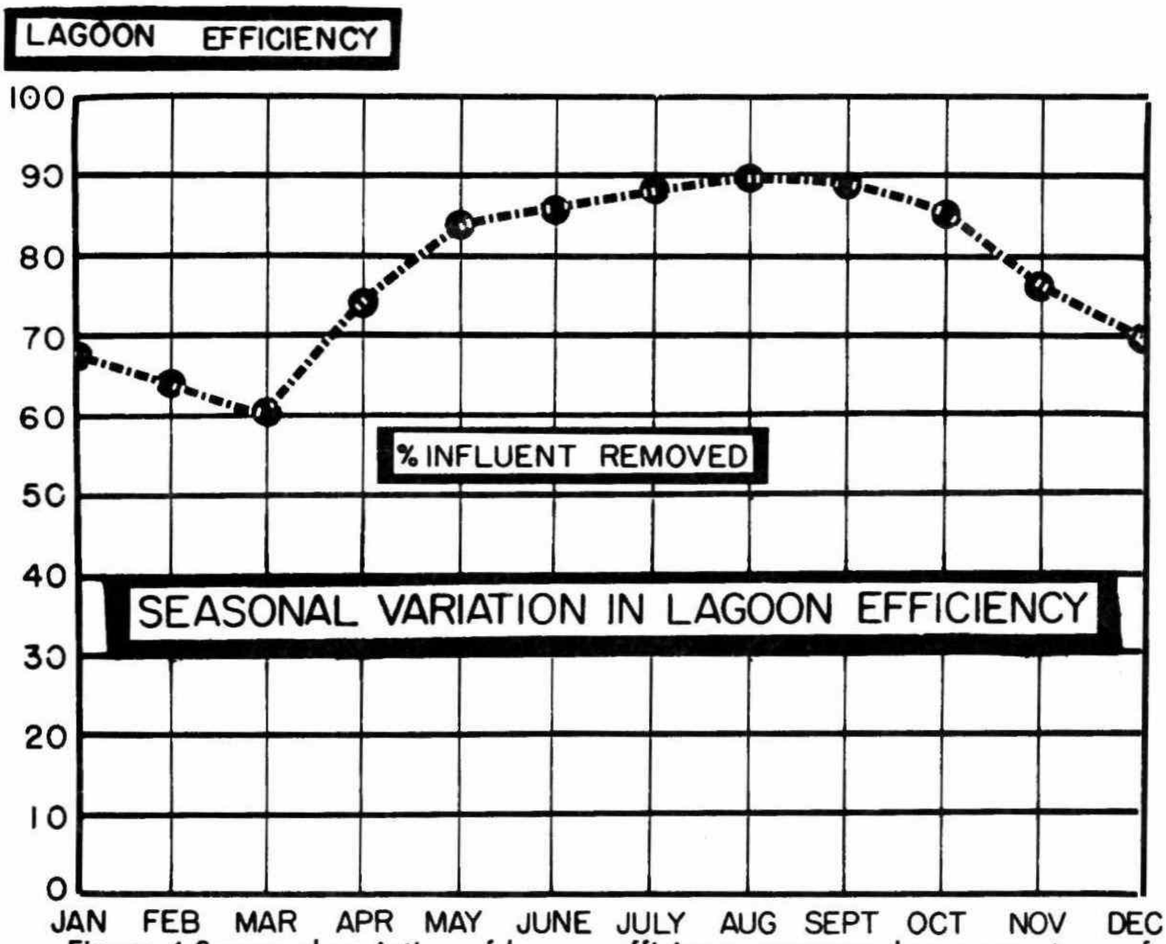


Figure 4 Seasonal variation of lagoon efficiency expressed as percentage of COD removed from influent

It follows that the strength of the treated effluent approximates the concentration within the basin itself. Due to the large volume of waste present in the basin, it would not be economically feasible to provide sufficient horsepower in the aeration and mixing units to completely mix the lagoon contents and prevent any sedimentation. Some sludge solids will deposit on the bottom between the aerators and give rise to some anaerobic activity. The decomposition on the bottom results in the formation of hydrogen sulphide which is converted to sulfuric acid by the aerobic blanket at the top.

The waste treatment facilities at the Canada Starch have been operating since March 1973. However, due to the early problems of acclimatization, and abnormal production in the summer and fall of 1973 caused by a labour dispute, we will concern ourselves just with the operation of the lagoon since 1973.

The major components of the wastes treated are evaporator condensates which range between 32° and 49°C and process wash waters which vary between 3° and 26°C depending upon the season and the product mix the plant is producing. The resulting waste pumped to the lagoon varies between 10° and 35°C. This coupled with the ambient temperature results in the lagoon having to operate in temperatures between 1° and 26°C as shown in Figure (3). The rapid increases in temperature indicated for the periods March - April, and July - August can be particularly troublesome if the lagoon is subjected to any sustained shock loading. The increased rate of microbiological growth caused by the added nutrients and temperature can quickly exceed the system's ability to supply oxygen. If the oxygen requirement is not satisfied the lagoon can go anaerobic.

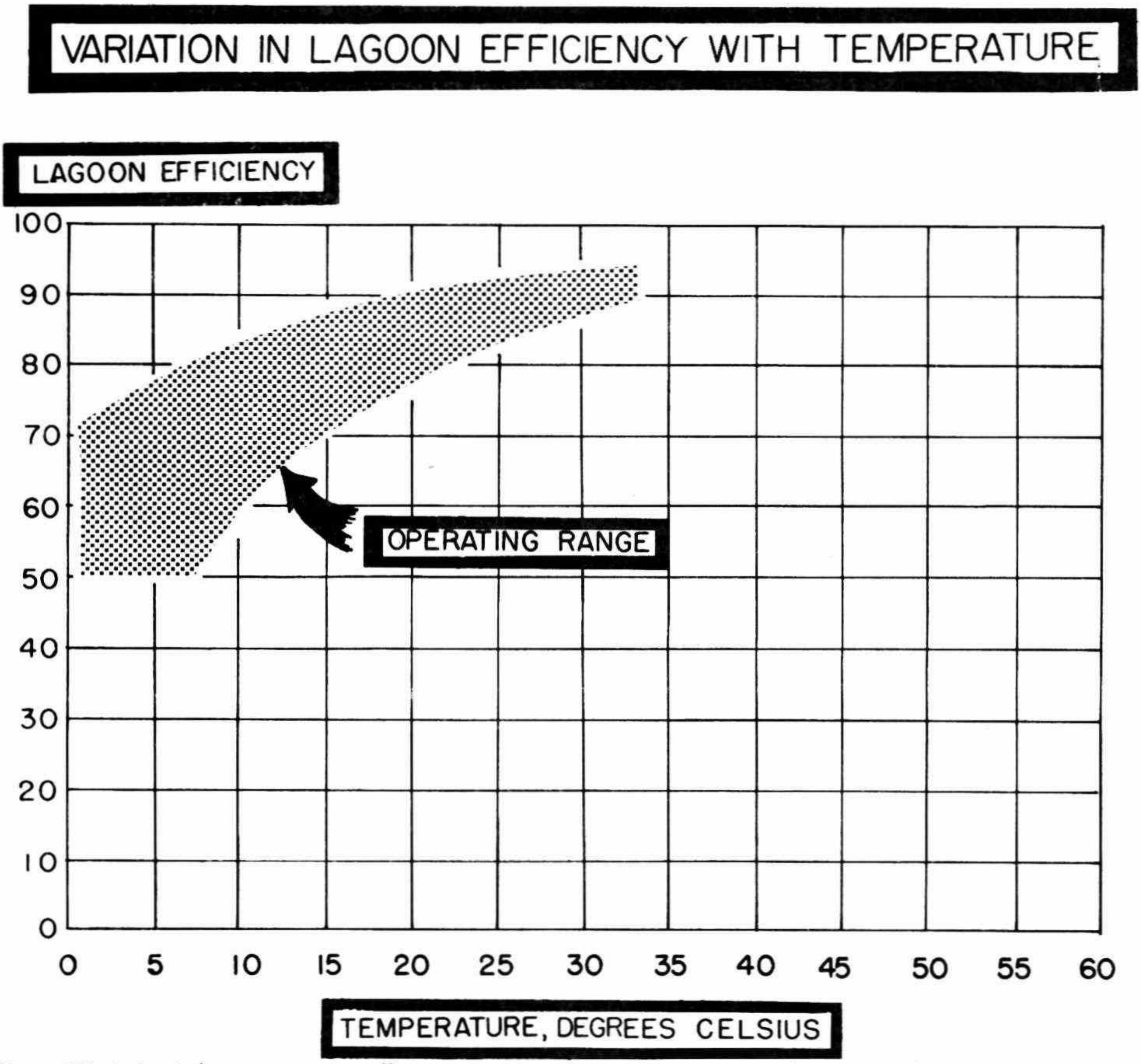


Figure 5 Variation in lagoon operating efficiency at various temperatures. Data is the average of two years results.

In most industrial applications the use of BOD as a measure of the strength of the waste is not practical. By the time the 5 day test is completed, it is too late to do anything about it. Consequently other methods that can be carried out on an on-line basis must be used. For expediency, we have chosen to use COD (Chemical Oxygen Demand) as our working unit. The efficiency of the lagoon has been calculated as the percentage of the COD removed from the influent stream. The efficiency of the treatment plant varies through the year from 55 to 90 percent depending upon the temperature and the product mix as shown in Figure (4). If we transfer the same data to show the effect of temperature on lagoon efficiency, Figure (5), it is interesting to note the range of efficiency broadens as the temperature decreases. It would appear that the flora is less able to adapt to changes in the substrate as the temperature falls below 15°C. However, even at 1°C efficiencies as high as 70% have been realized.

As mentioned earlier, it would not be economically feasible to provide sufficient mixing in such a large volume of water to keep the suspended solids from stratifying. The mixer just supplies sufficient agitation to adequately disperse the oxygen in the water. As a result, the oxygen levels through the lagoon itself may vary considerably due to inadequate total mixing and due to settling to form an anaerobic zone.

With the submerged turbine, the impeller is mounted close to the bottom of the lagoon. From a design standpoint, this should have provided sufficient mixing to maintain an aerobic zone at least 140 feet in diameter and allow a controlled deposition of solids in the remaining zone.

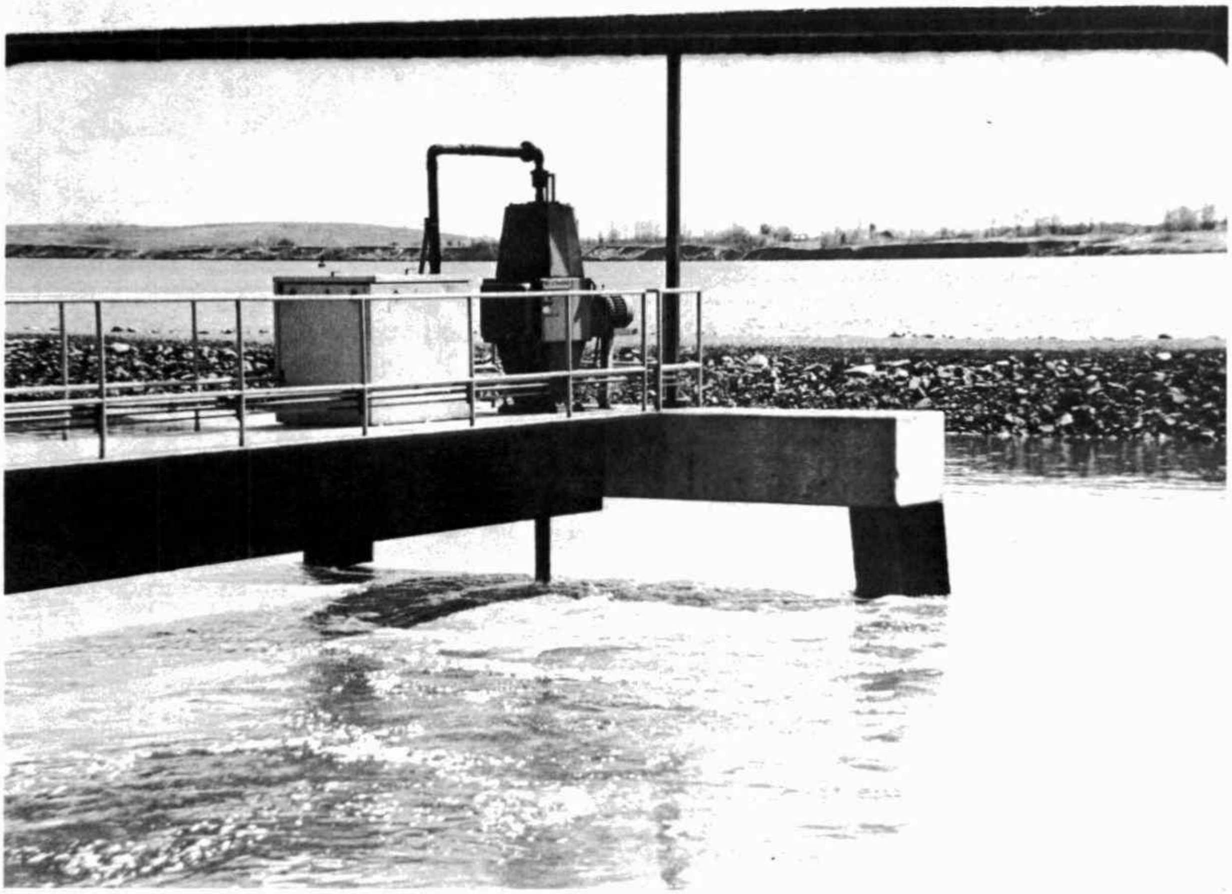


Photo 6 View showing platform aerator and mixer. The blowing unit is enclosed in an acoustic metal box.

Photo 7 View of pile and baffle around the aerator. Water surface shows the small degree of foaming and surface disturbance.

To verify the action of the aerators in the lagoon, a Yellow Springs Instrument's dissolved oxygen meter was purchased together with a pressure and temperature compensated probe (YSI-5739). The lagoon was sounded at various positions between the aerators. The dissolved oxygen isopleths are shown in Figure 6. This shows a simplified cross section of the oxygen concentration between the two aerators. The isopleths indicate the mixing zone is extensive and very close to the 140 foot design figure. There is a small tendency toward anaerobic activity in the more quiescent zone between the two aerators and virtually none in the normal mixing zone. By measuring the dissolved oxygen profiles between the aerators in the lagoon we have a better understanding of the balance between the two aerobic and anaerobic cultures.

The loss of the balance in an aerobic/anaerobic system is generally brought about by some form of shock loading which may stimulate the growth of the aerobic bacteria to such an extent that they consume all the available oxygen in the lagoon faster than it can be replaced. The system is then forced to go anaerobic.

It has been long established that sodium nitrate can be effectively used to reduce and delay sulphide production in sewage (10-13). The waste treatment plant at Cardinal is in very close proximity to the town residential area. Consequently, any hint of anaerobic activity is immediately noticed. As an insurance measure an operating policy has been followed of matching any shock loading greater than 1500 ppm COD (6000 lbs. COD) with a similar number of pounds of sodium nitrate, i.e., 1500 lbs. This practice so far has been successful.

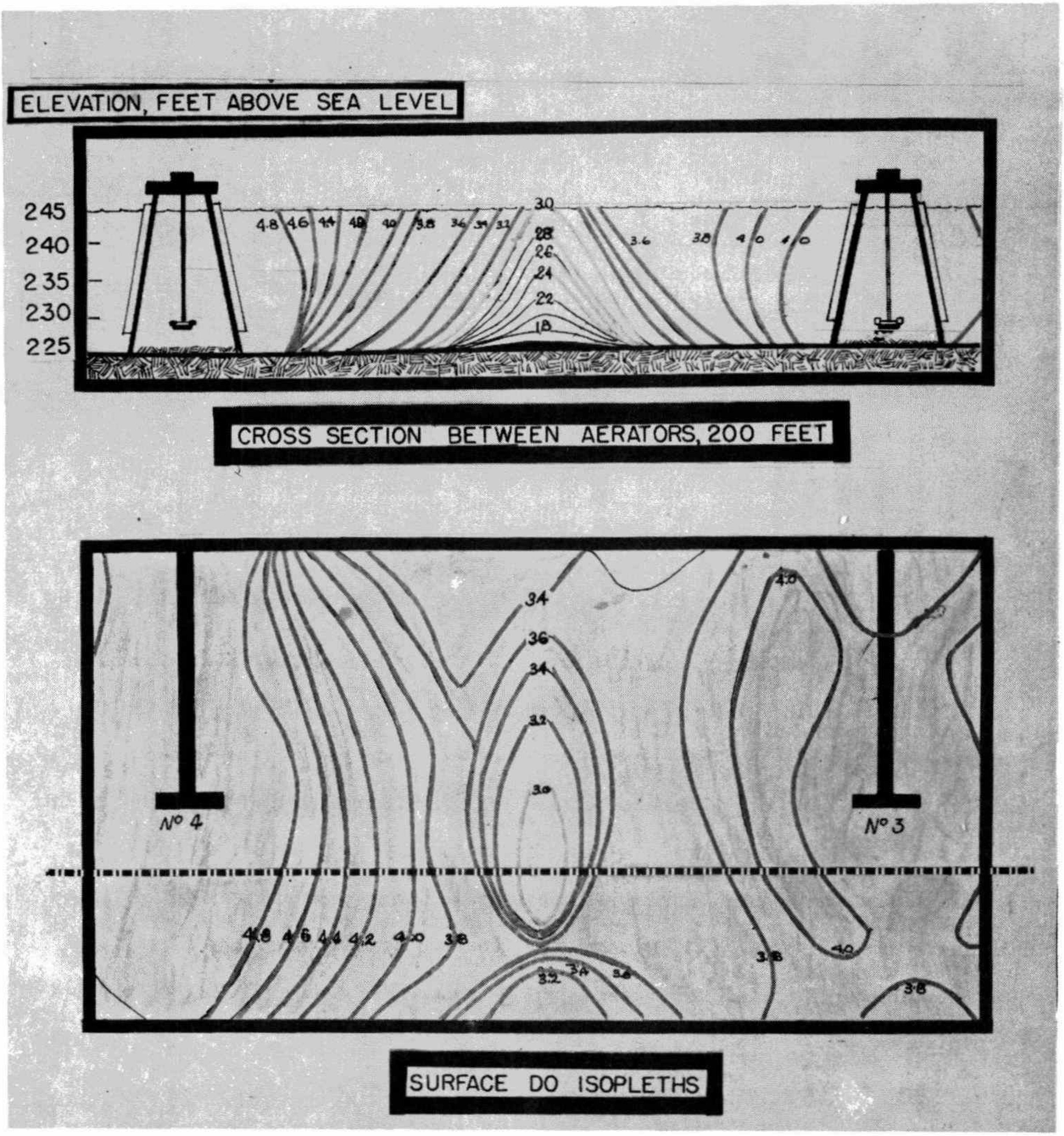


Figure 6 Dissolved oxygen isopleths of lagoon taken between two center aerators.

The lagoon itself is well buffered and can absorb large swings or shock loadings in pH without any significant change in effluent pH or COD concentrations as shown in Table 2.

TABLE 2

Data Illustrating a pH Shock Loading to Lagoon @ 0.5 MGPD in 12.5 Million Gallons

	Influent		Effluent	
Date	COD	pH	COD	pH
5/26/74	320	5.8	74	6.6
5/27/74	1070	10.1	66	6.8
5/28/74	660	6.5	66	6.6
5/29/74	430	5.7	64	6.6
5/30/74	420	5.6	62	6.6
5/31/74	410	5.4	74	6.5

Over the past 2½ years the lagoon has been subjected to wide variations in hydraulic loadings without any noticeable change in efficiency. Some of the hydraulic shock has been by design. As an example, the refinery operator has the ability to remotely divert the entire refinery flow of 1500-3000 gallons/minute into the lagoon in the event of a significant disturbance. When this option has been executed the average monthly residence time has been reduced by up to 10 days from the normal 30. By comparing the same months, where the operating temperatures are very similar, there are no significant changes in the operating efficiency.

Monitoring System:

To maintain the privilege of returning 90-95% of the plant water untreated to the St. Lawrence River, an elaborate monitoring system was set up to detect the presence of any process upset or spill that might end up in the river. To do this, the Technicon Monitor IV, a continuous on-line analyzer used to measure the COD in waste streams was chosen. In total, five of these stations

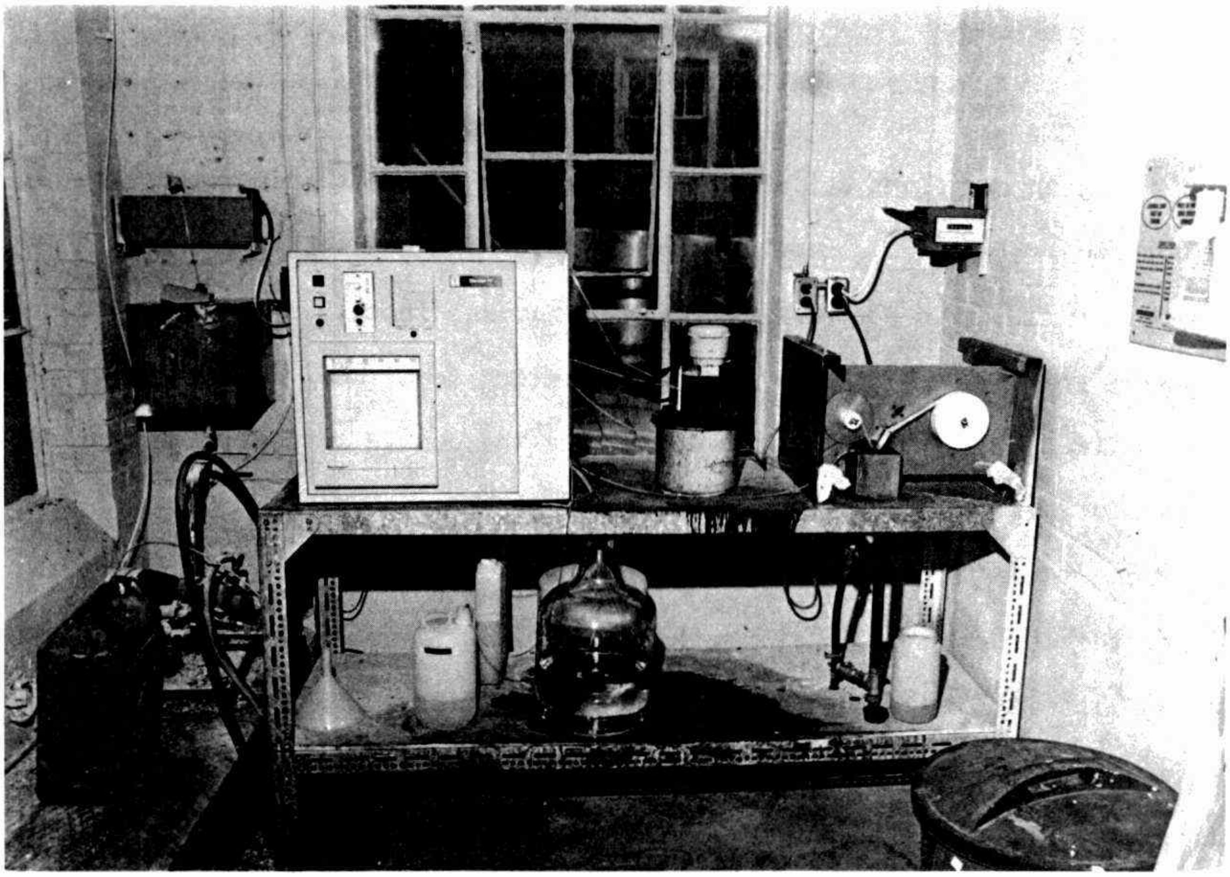


Photo 8 Technicon Monitor IV field station showing filter digestion bath, monitor, flowmeter and teleletry.

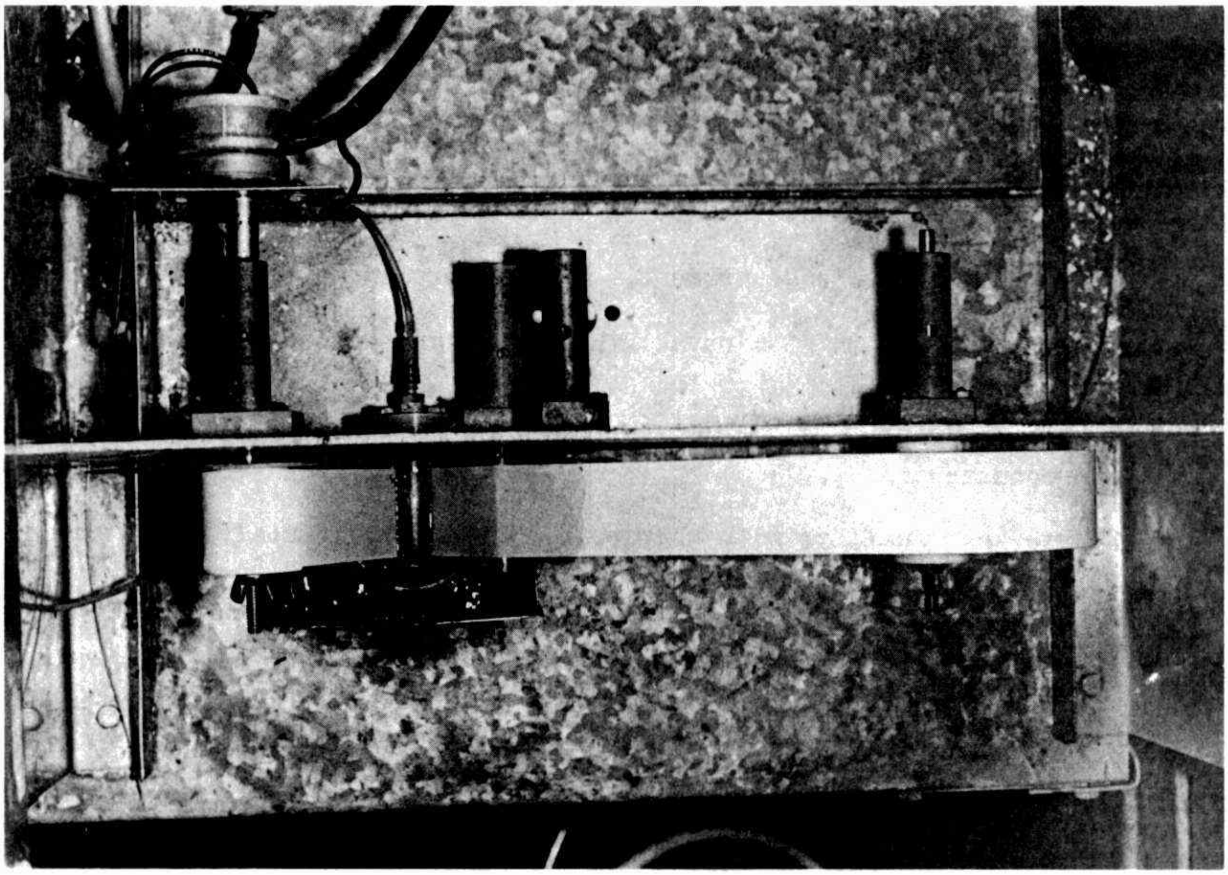


Photo 9 Top view of the continuous filter used for the incoming sample to the Technicon IV's.

were set up, 3 on our plant outfalls, 1 on the triple effect evaporator which serves both to isolate the source of contamination and to pick up the signal quicker than in the main outfall. The fifth unit was installed on the influent to the waste treatment plant to alert the operating department of any severe "shock" loading. These monitoring systems make the people responsible for the upset aware of the problem a few minutes after it has occurred.

Each of the five monitoring stations has a sample weir, a continuous filter for the stream entering the Technicon Monitor IV unit, a continuous composite sample (unfiltered) for laboratory analysis of the daily COD, pH and suspended solids; a flow meter so the actual lbs./day of lost material can be calculated, a Technicon Monitor IV unit and recorder, and the telemetry to transmit the signal to the gatehouse where an alarm system has been set up.

Any product or process loss of approximately 50 ppm COD triggers an alarm in the gatehouse. The attendant then notifies the foreman in charge of the area where the problem has occurred and records his name on the chart along side the peak. The foreman then follows a set procedure to locate the source of the loss, corrects the problem and records the action taken on a "shot" report which is returned to our yield and loss department. If the foreman in charge in unable to correct the problem within 30 minutes, then a designated senior plant official must be notified day or night. The action to curtail the loss is started within minutes of its occurrence.

For those, not familiar with the Technicon Monitor IV analyzers used for COD determinations, the sample is pumped through mixing coils where the various reagents are added in the required amount (Figure 7). The quantity of reagent is controlled both by its concentration and the diameter of the pump tubes used to introduce the reagent. The sample is refluxed with the digestant (a potassium dichromate-sulphuric acid silver sulfate mixture) and the orange-yellow hexavalent

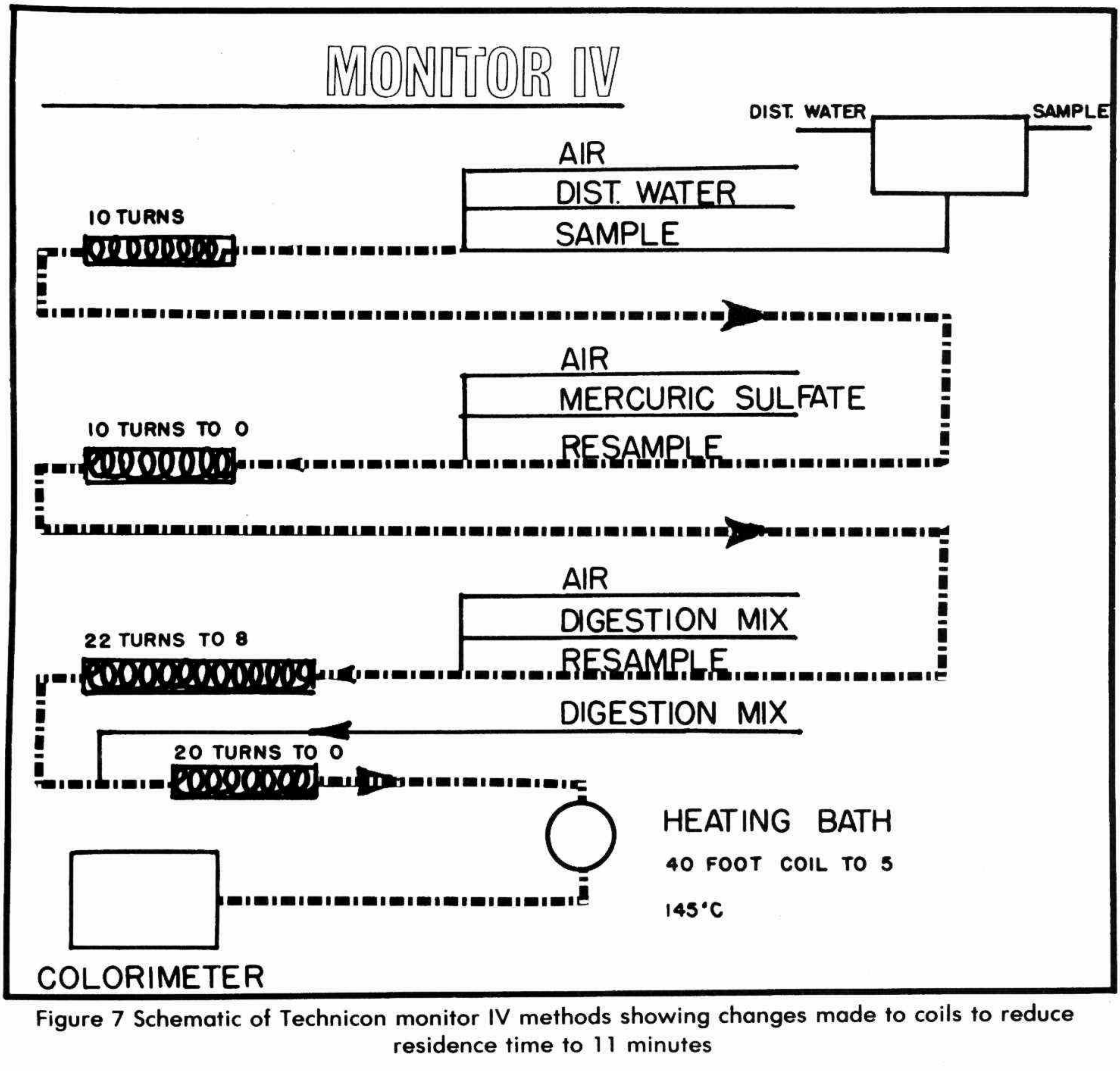


Figure 7 Schematic of Technicon monitor IV methods showing changes made to coils to reduce residence time to 11 minutes

chromium is reduced to the green trivalent state. This reduction of colour is measured by a colorimeter and the results recorded as ppm COD (14). In the analysis a mercuric salt is used to complex and eliminate any chloride interference (15).

One of the major drawbacks of the Technicon Monitor IV units in our application was the presence of a 28 minute lag time between the samples introduction and the response signal. Much of this time is taken up by the distance the sample travels in the mixing coils and the time (length of coils) resident in the digestion bath. Shortening these lengths without an appreciable loss in signal strength would greatly improve its effectiveness. The 40 foot glass coil in the digestion bath was reduced to 5 feet (16). The four remaining coils were left as follows:

1. First coil was left untouched to allow the mixing of the sample with distilled water.
2. Second coil was eliminated.
3. Third coil was reduced from 22 turns to 8.
4. Fourth coil was replaced by an injection fitting.

The net result was a reduction in residence time from 28 minutes to eleven minutes. There was a small loss in accuracy, i.e., a ratio of modified to original value was 0.84. However, these units are intended to monitor and alarm a process upset and are not required to give an absolute COD value. By changing the sample size the absolute value may be achieved. The Monitoring system is the key to the pollution abatement program - PREVENTION RATHER THAN TREATMENT. Action to correct the upset is started within minutes rather than hours.

Cost of Pollution Abatement:

The pollution abatement program at Canada Starch was completed at a cost of $945,000 (expressed in 1973 dollars) with the aerobic facultative lagoon representing seventy percent of the total cost. This was accomplished at a fraction of the 1967 estimates due both to the great reduction in plant loading and the use of the old Gallop Canal and the facultative lagoon. The approximate construction costs are listed in Table 3.

TABLE 3

Approximate Cost of Pollution Abatement Program
(Based on 1973 Dollars)

Land acquisition and bldg. alterations	$55,000
Plant piping changes, forcemain, chlorination	$80,000
Elliott scrubber	$50,000
Berm construction, dredging, outfalls, rip-rap	$525,000
Aerators and platforms	$100,000
Instrumentation (Lagoon and Monitors)	$80,000
Electrical	$25,000
Total	$945,000

The operation of the lagoon is relatively simple and does not require an operator. The aerators are monitored in the powerhouse for any malfunction. The nutrients are added in the form of ammonium hydroxide to maintain a ratio of COD:N:P of 100:5:1. No phosphorus is added as the influent from the industrial sewer contains 0.9 ppm phosphorous. There are two full time technicians involved in maintaining the monitors and analyzing the composite waste and effluent streams.

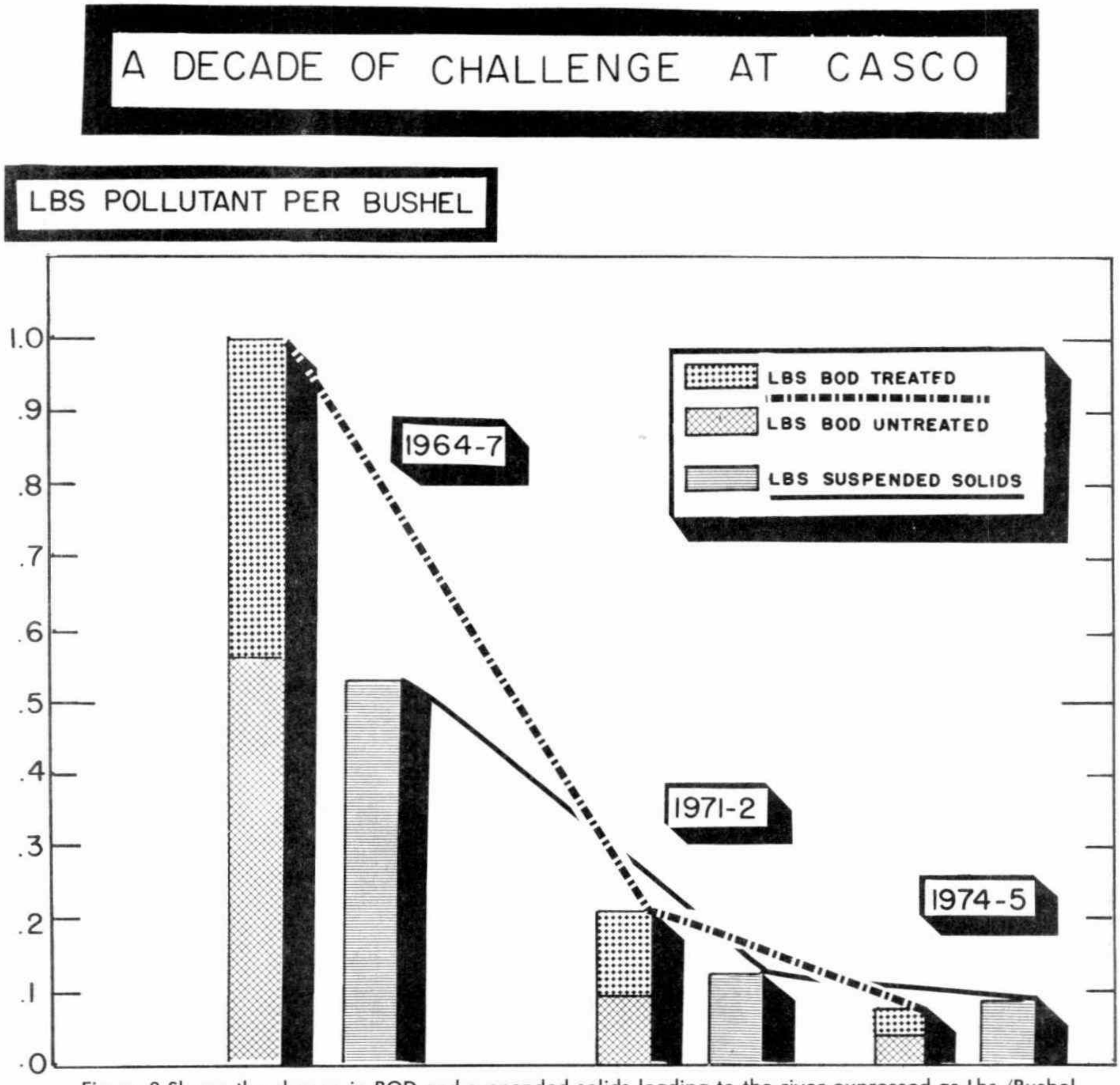


Figure 8 Shows the change in BOD and suspended solids loading to the river expressed as Lbs./Bushel

The operating costs are tabulated in Table 4 below:

TABLE 4.

Annual Operating Costs of Total Pollution Abatement Program

Depreciation @5%	\$47,250
Electrical Costs	\$16,900
Chemicals - Lagoon	\$11,000
- Monitors	\$ 6,000
Maintenance - Lagoon	\$20,000
- Monitors	\$ 9,000
Labour	\$30,000
Miscellaneous	\$ 2,000
Total	\$142,150

Over the past decade, the challenge of the "Sixties" has been met as we look at the large strides taken in name of ecology, (Figure 8). The lbs. of BOD/bu. have been reduced from 1.0 to 0.07 and the suspended solids from 0.53 to 0.083 lbs./bu. Although we have not resolved all our problems, work is progressing to improve many of the waste streams. Our success may also be reflected by continued emphasis on good operating practice and maintenance. New engineering projects are designed with pollution control in mind. Protecting our environment is our corporate responsibility. We feel confident that the wet milling industry will meet the challenge of the "Seventies" and "Eighties". We hope this presentation may in some way help you in your efforts toward pollution abatement.

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ENERGY ANALYSIS OF RESOURCE RECOVERY OPTIONS

This paper discusses the methodologies which can be used for energy analysis, suggests a suitable approach for the assessment of resource recovery options in the Province of Ontario, and analyzes five materials in the garbage. One of the major conclusions of the study undertaken is that no one methodology for energy analysis can be applied universally. The mechanics of carrying out the analysis are very simple, such as the definition of symbols, and methods of illustrating the processes under consideration by appropriate flow-sheets. However, aspects of the problem which are not simple, include defining the objectives of the analysis, setting the system boundary and obtaining reliable data.

The primary objective of the study was to assess the energy cost of resource recovery options for the management of municipal waste. These options include the necessary steps to reduce the quantity of waste generated, source separation programs and the mechanical processing of waste to recover energy and materials.

by

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Energy Analysis of Resource Recovery Options

by

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Energy analysis is defined as the determination of the energy sequestered in the process of making a good or service within the framework of an agreed set of conventions or applying the information so obtained.

While anyone who has done a process heat balance has in effect done an energy analysis, it is only within the last five or ten years that it has begun to be applied in a widespread fashion to systems rather than individual process plants. For the process plants, the data were needed for design purposes. For the systems the data are useful in a number of ways, including guiding policy decisions.

To provide an analogy to a more familiar analytical method, EA can be compared to economic analysis, the difference being that dollars are replaced by Btus. This does not mean that EA can replace economic analysis; it does provide another means of evaluating projects and policy alternatives in addition to such things as land, labour, water, protein, etc. Its chief benefit is, therefore, as a supplement to other widely used tools of analysis.

In the present project EA was used to examine alternative methods of recovering resources from municipal wastes and to compare the

energy needed to recover and reuse materials in the waste stream with the energy required to make them from raw resources or the energy which could be derived from them.

Because EA is still a relatively new field of study, part of the program was devoted to developing a suitable methodology. This included establishing guidelines and defining terms and system boundaries. This paper discusses some of the issues involved in choosing the methodology, examines the results of applying EA to four components in municipal waste streams and outlines the implications for Ontario's resource recovery programs.

THE RESOURCE RECOVERY PROBLEM

Figure 1 illustrates the problem which was analysed. Manufactured goods end in a pile of discarded materials or municipal refuse which must be disposed of. There are essentially three disposal alternatives:

(1) disposal to landfill,
(2) recovery from the waste and recycle to manufacture secondary products and
(3) incinerate to recover the energy content or convert to a refuse-derived fuel.

Each of these alternatives has associated with it certain energy requirements. The question is, how do these energy requirements compare? The answer can be found in an energy analysis.

ENERGY ANALYSIS METHODOLOGY

Before describing the results of the energy analyses, the methodology will be examined briefly. The methods to be described are based on the recommendations of an energy analysis workshop held in Sweden under the auspices of the International Federation of Institutes for Advanced Study (IFIAS)[1]. In carrying out the analyses the recommendations were adapted to the objectives of this particular study.

The first, and possibly the most important, part of the analysis is choosing the objectives. These choices determine the type of analysis required, the boundaries of the system, the energy requirement term and the detail needed in the analysis. Some of the more important aspects of these factors will now be described.

There are essentially two types of energy analyses, namely, process analysis and input-output analysis.

Process analysis, as the name implies, involves a detailed study of the production and manufacturing steps involved in producing a good or service. In theory, the energy requirement of each component in the finished product is traced back until all the raw, in-ground resources needed in its manufacture have been determined. In practice, it is not practical to carry out the analysis in this much depth as the contributions from each subsequently more remote step grow smaller and, for most products, only one or two prior steps are needed to obtain an acceptable accuracy in the analysis. Beyond these first few steps the energy required can be estimated on an aggregated basis from data obtained from an input-output analysis.

Input-output analysis is borrowed directly from economic input-output tables which show the values of sales to each industry from every other industry and to final demand. By manipulating the matrices and using factors to convert dollars to energy, the total energy inputs to each sector of the standard industrial classifications can be determined.

The key features of process analysis and input-output analysis are reviewed in Figure 2. Process analysis usually begins with the preparation of a flowchart similar to that for a plant design. The energy inputs for each process step from raw material acquisition to the finished product are then determined. Fuel inputs are measured directly and no conversion is, therefore, necessary. It is the only method by which specific energy requirements can be determined. The process analysis can

be used to obtain any one, or all, of the most common energy requirements: gross energy requirement, net energy requirement, process energy requirement and apparent energy requirement.

These energy requirements differ in the following ways: the gross energy requirement is defined as the amount of energy source which is sequestered by the process of making a good or service; the net energy requirement omits the energy sequestered in a product which has potential as a fuel. For example, in manufacturing plastics, the difference between the GER and the NER is the energy which is potentially recoverable from the product. The process energy requirement excludes the actual energy content of feedstocks which have alternative uses as fuels, although the decision regarding which feedstocks do have potential as fuels is sometimes difficult to make. Wood used in papermaking is a case in point and is discussed later. The apparent energy requirement does not include the energy needed to produce fuels from in-ground resources. Its use has been discouraged but, in our view, it does have some merit in a province such as Ontario which is a major consumer, but not a producer, of energy. This is because Ontario needs to optimize the use of <u>delivered</u> energy. Thus, energy savings need to be compared on the basis of energy made available for an alternative use within the province, rather than as in-ground resources elsewhere. The issue is complicated further if the "quality" of gas, oil, and coal as fuels is considered, but for this study the decision was to use AER for most purposes. Conversion to GER through appropriate factors is relatively easy.

Input-output analyses are done from a matrix of industrial economic data. By matrix multiplication and inversion the total energy requirement of any commodity can be obtained from the appropriate column of the resulting matrix. The conversion from dollars to energy, usually as kWh in North America but as joules elsewhere and increasingly here, is done by applying a factor determined from other data. Since the raw input-output data are aggregated by industry in some form of standard industrial classification, the answers are also highly aggregated. Using I/O analysis,

the GER for an entire industry is obtained.

To describe the basic difference between process analysis and input-output analysis the IFIAS workshop noted:

> "If the objective of the energy analysis is to establish the GER for a kilogram of pineapples, input-output tables are of no help whatsoever. But, if the objective is to find out the average GER of the whole agricultural system, the input-output tables will provide the information swiftly, usually to a high degree of accuracy."

Figure 3 illustrates a flowchart of a process analysis. Energy associated with each step can be traced back to in-ground resources such as coal, oil or gas or, if the AER is being determined, only the upgraded fuels, such as gasoline and coke, may be counted. Secondary energy such as steam and electricity must also be traced back to the appropriate sources. Energy for raw materials and their transportation must be included. Energy for manufacturing includes primary fuel inputs, electricity (and its fuel equivalent) and the energy associated with capital equipment. Finally, energy for transporting processed goods, which may include packaging, is also required.

It is difficult to generalize broadly about the quantitative aspects of energy analysis at this point. However, it should be pointed out that the energy associated with the capital requirements is usually less than 10% of the total and is often 5% or less. An error of 50% in this particular item would only affect the total requirements by a few percentage points at most. Input-output analysis for construction and equipment in broad, highly-aggregated terms is, therefore, usually accurate enough to determine capital associated energy requirements.

One additional issue which must be settled before the energy analysis can be done is the boundary of the system. Figure 4 uses aluminum as an example of the effect of system boundary on the energy

requirements. Taking the world as a system boundary, one ton of aluminum requires about 245 million Btu. About 13 million of the total are needed to mine and transport the bauxite to Canada. Thus, from a Canadian point of view, energy input to aluminum production only requires about 232 million Btu. Since all the primary aluminum made in Canada comes from either Quebec or British Columbia, then, from Ontario's point of view, only a minute amount of the total energy requirement, associated with transportation within the Province's borders, is used to produce aluminum ingots. The effect of the choice of system boundary on the apparent benefits of recycling aluminum is discussed later.

To summarize the methodology, the objectives of the energy analysis must be chosen, keeping in mind the limitations of the types of energy analysis, the energy requirement term, the boundaries of the system and the detail needed in the analysis.

RECOVERY FROM MUNICIPAL WASTE

With the above background on methodology, we can now begin to discuss the actual energy analyses. Resource recovery from municipal waste is still in its infancy as a technology. Ontario is currently building an experimental plant to study the optimum configuration and to test the suitability of equipment for resource recovery. To estimate energy requirements for waste processing, a flowsheet was chosen on the basis of what was considered to be the most likely processing scheme. The flowsheet is illustrated in Figure 5. Refuse will go through a primary shredder and then be air classified. The light fraction will be used as a fuel and the heavy fraction magnetically separated to recover ferrous metal which is shredded further before being ready for sale.

The non-magnetic fraction is screened to yield a "dirty" glass fraction and a heavy organic fraction. The "dirty" glass is air classified to produce a finished glass fraction and an organic fraction which is combined with the organic fraction from screening to produce a heavy fuel fraction. The total energy required has been calculated as 701 thousand Btu/ton.

In subsequent applications we decided that the fairest approach to distributing energy among the various product fractions was to assume that each required the same energy in spite of slight differences in processing. When actual plant data are available and markets are established the products and by-products can be identified and a more rational distribution can be made.

The major product streams from the plant are:

(1) a light fuel fraction,
(2) a heavy fuel fraction,
(3) ferrous metal and
(4) glass

The light fuel fraction will be largely paper and plastic film. It may also be possible to separate an aluminum and plastic fraction when the technology has been developed. These components were, therefore, the ones of most obvious significance in terms of energy analysis and the study proceeded to examine the energy implications of recycling these resources from the municipal waste stream. The four which are discussed in this paper are:

(1) newspaper,
(2) glass,
(3) steel and
(4) aluminum

NEWSPAPER

The energy aspects of resource recovery for newspaper were examined by determining:

(1) the energy required to make virgin or primary newspaper and to make secondary newspaper from recovered municipal waste, and
(2) the energy saved by incinerating newspaper, and by producing electricity, steam, gas and oil from newspaper by various processes.

A few of the alternative flowsheets and a summary showing the savings attainable by the various processes are presented here.

Figure 6 gives a simplified flowsheet for primary newspaper production and shows the energy requirements for each step. It should be noted that trees were not considered to be an energy source for the purposes of this analysis.

The figure shows that 1.53 tons of trees are harvested and processed to yield one ton of primary newspaper. Taking into account credits for heat supplied by waste bark and other fuels, the total energy requirement is 24.7 million Btu/ton of newspaper. If the trees were considered to have an alternative application as fuel, the total energy requirement would roughly double.

Several other interesting points might be noted: The energy required for capital is just under 5% of the total; sulphite pulping is about 60% to 70% more energy intensive per unit of material produced; over 70% of the energy required is associated with the pulping operations.

Figure 7 presents an energy analysis of secondary newspaper from recovered waste paper. The total energy required is about 20 million Btu/ton. Essentially 90% of the energy required is associated with the pulping, de-inking and papermaking aspects of the recycling system. Thus energy inputs from the recycling plant are relatively unimportant from an energy point of view. Again, capital related energy is just under 5% of the total.

The energy which can be recovered from the incineration of newspaper in terms of the net fossil fuel saving is given in Figure 8. This simplified flowsheet is based on raising steam by direct incineration. The fossil fuel saved assumes an efficiency of 87.5% for producing steam from fossil fuel. The net conversion efficiency from fuel value of the newspaper to fossil fuel savings is 76.7%. Capital related energy requirements are below 1% of the net fossil fuel saving.

The results from the systems discussed above, along with various

other methods of recovering energy from waste newspaper are summarized in Figure 9. The first three processes listed involve the direct use of the waste newspaper to produce steam, electricity or process heat, the next three cover various gasification and liquid fuel production alternatives and the last looks at the potential saving from recycling. The most effective alternatives are those which use the waste newspaper directly or which convert the waste to useful fuel at high efficiency. Recycling results in a net fossil fuel saving of only one-third that of the other efficient alternatives.

The basic reason for this is that the trees were not considered to be an energy source in the analysis, but the waste product has been given a fuel value. This is consistent with the present use patterns in Ontario. If wood becomes an important fuel, then its energy content should be included in the analysis. Recycling will then become the favoured alternative from an energy point of view.

GLASS

Figures 10 and 11 present the energy requirements to produce glass from virgin materials and from recycled glass in refuse. Primary glass requires almost 19 million But/ton. The greatest portion of this energy (82%) is the fuel required in glass manufacture. Only about 3% of the total glass manufacturing energy is associated with the capital requirements. The other major item (12%) is for soda ash production. This is high in Ontario since essentially 100% of the soda ash is prepared synthetically whereas about 60% is synthetic in the U.S. Soda ash from natural sources requires only 20 to 25% of the energy needed to produce synthetic material. Secondary glass requires about 17 million Btu/ton, assuming that 2 tons of glass in the refuse are treated for every ton of glass recovered. As with primary glass most of the energy (87%) is used in the melting process. Overall savings of about 2 million Btu/ton or roughly 10% can be achieved by recycling.

STEEL

Steel is the next item considered. Figure 12 gives a very simplified view of integrated steel-making from ore to raw steel. Raw materials, the chief ones being iron ore, coal and limestone, are converted to high grade iron oxide, coke and lime. These materials are fed to a blast furnace where pig iron is made. Pig iron is converted to steel through one of three processes: open hearth, basic oxygen or electric furnaces. The molten steel is cast into ingots or continuous shapes to yield raw steel, the point at which the present analysis ends.

Using the mix of open hearth/basic oxygen/electric furnace production in the U.S., the average primary energy requirement for raw steel is about 20 million Btu/ton, excluding capital related energy. None of the published literature included capital related energy but one extimate of $400 per ton of annual steel capacity was made in 1972. From this, an estimate of about 1 million Btu/ton for capital related energy was made. Again, this figure is roughly 5% of total energy requirements.

Using data published by Statistics Canada and the mix of open hearth/basic oxygen/electric furnace steel production in Ontario, and including iron ore mining and beneficiation and miscellaneous energy not specifically included in the Statistics Canada data, the total energy required for an average ton of raw steel in Ontario is 24.8 million Btu.

Recycling steel from recovered tin-plate, the material used for food and beverage containers, is still relatively novel technology. Literature data on the energy required to prepare tin-plate from municipal waste for use as steelmaking scrap were not available. A flowsheet for the necessary process steps is given in Figure 13. The energy requirements for the scrap detinning and cleaning steps were estimated on the basis of experience and should be confirmed by further study. The total energy required for secondary raw steel production is about 17 million Btu/ton.

Depending on which data are used, recycling steel will save from

about 3 to 8 million Btu/ton. This amounts to 15 to 40% of the average energy requirement. One study reported that 39% of the energy could be saved by 100% recycling of all-steel beverage containers. For 75% recycle, the assumed efficiency of the recovery process from municipal refuse, the saving would be about 30% and the agreement with the 15 to 40% range is good.

ALUMINUM

Production of aluminum is very energy intensive compared to newspaper, glass and raw steel. The latter three products require roughly 20 million Btu/ton. As shown in Figure 14, primary aluminum requires 245 million Btu/ton. Over 60% of the total is used in electrolytic reduction with an additional 15% of the total input also coming in this stage in the form of carbon, cryolite and aluminum fluoride.

The electrical energy needed for aluminum production was converted to fossil fuel requirement at a conversion efficiency of 32% even though essentially all the power is hydraulically generated. The rationale for this is that, if the power was available, it would result in an equivalent reduction in thermal power generation, although it is recognized that this would not be strictly true.

Recycling aluminum from municipal waste would require about 11 million Btu/ton as shown in Figure 15. As noted earlier, the energy cost to Ontario is higher for recycled aluminum, but the overall benefits to Canada are huge with the reduction in energy requirement being about 95%.

POTENTIAL FOR SAVING ENERGY

Figure 16 summarizes the energy savings which can be realized by recycling each of the four materials discussed and also gives the energy which can be recovered by using newspaper as fuel. The data show savings of about 2 to 5 million Btu/ton for newspaper, glass and steel recycling. The savings represent roughly 10 to 20% of the energy used in making these primary products. For newspaper incineration, up to 14×10^6 Btu/ton of fuel equivalent can be saved. This represents over 50% of the energy used in making the newspaper.

What are the implications of these results for resource recovery policy and programs in Ontario?

ONTARIO'S RESOURCE RECOVERY PROGRAM

Ontario's Resource Recovery Program recognizes that a complete solution to the problems of waste management will require a number of different basic approaches which must be pursued in parallel to achieve success. Summarily these approaches are:

1. reduction in the quantity of material produced which is likely to result in waste;
2. changes in the methods of manufacture or types of material used to simplify the separation and reclamation of the wastes produced;
3. separation of some elements of the waste at source, either at the household, commercial or industrial level;
4. planned, co-ordinated waste management systems;
5. central resource recovery plants;
6. possible additional processing facilities for materials separated at the central plants;
7. encouragement for the re-use of reclaimed material, and the development of new uses for this material.

In the wake of the energy crises, much publicity has been given to energy analysis and there has been a suggestion that energy units could provide the basis for replacing our current monetary system. It should be stressed that energy analysis is not a panacaea and does not replace the economic analysis which must be carried out on each resource recovery option which is being considered. However, there are a bewildering array of options which are reportedly available and a similar array of claims made by proponents of resource recovery systems.

At times it is difficult, if not impossible, to compare efficiency claims of one system against another since a common reporting format has not

been available. In this area, the energy analysis methodology which has been developed will be of particular significance in establishing strategies for future waste management systems leading to resource recovery of energy and materials from municipal solid waste.

POLICY DEVELOPMENT

The Energy Analysis of Resource Recovery has shown that the Ontario Program for Resource Recovery should emphasize energy recovery and at the same time maintain flexibility of processing options so that, in future years, material recovery can be incorporated as an alternative as market conditions change. On this basis, demonstration programs such as the Watts from Waste Project to utilize refuse derived fuel at a thermal generating station and use of refuse derived fuel by the cement industry are of paramount importance to the development of Ontario's program. In addition, we are exploring the possibilities of other industrial uses of converting municipal waste to refuse derived fuel.

With respect to the development of strategies which will result in a reduction of the quantities of waste being produced, energy analysis will be of assistance but may or may not be the major factor in any final decision. Energy analysis will also provide a tool for reviewing any new material or products which might come on the market and which, of course, must eventually be considered as part of the waste stream which will require processing or disposal.

It can be seen that energy analysis will become an increasingly important tool in the development of waste management and resource recovery strategies.

To conclude with a balanced perspective on the importance of energy analysis, the following quote[2] is offered:

> "Energy analysis will not solve the world's problems, it will not replace economic analysis, it will not provide easy answers to difficult decisions. It is

just one more way of describing societal activities, in terms of a very important physical parameter, and, hopefully, it can lead to improved decision-making now that the importance of energy use (along with many other factors) has been recognized."

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1. Energy Analysis Workshop on Methodology and Conventions, International Federation of Institutes for Advanced Study, Guldsmedshyttan, Sweden, August, 1974. (Available from: IFIAS, Nobel House, Sturegatan 14, Box 5344 S-102, 46, Stockholm, Sweden).

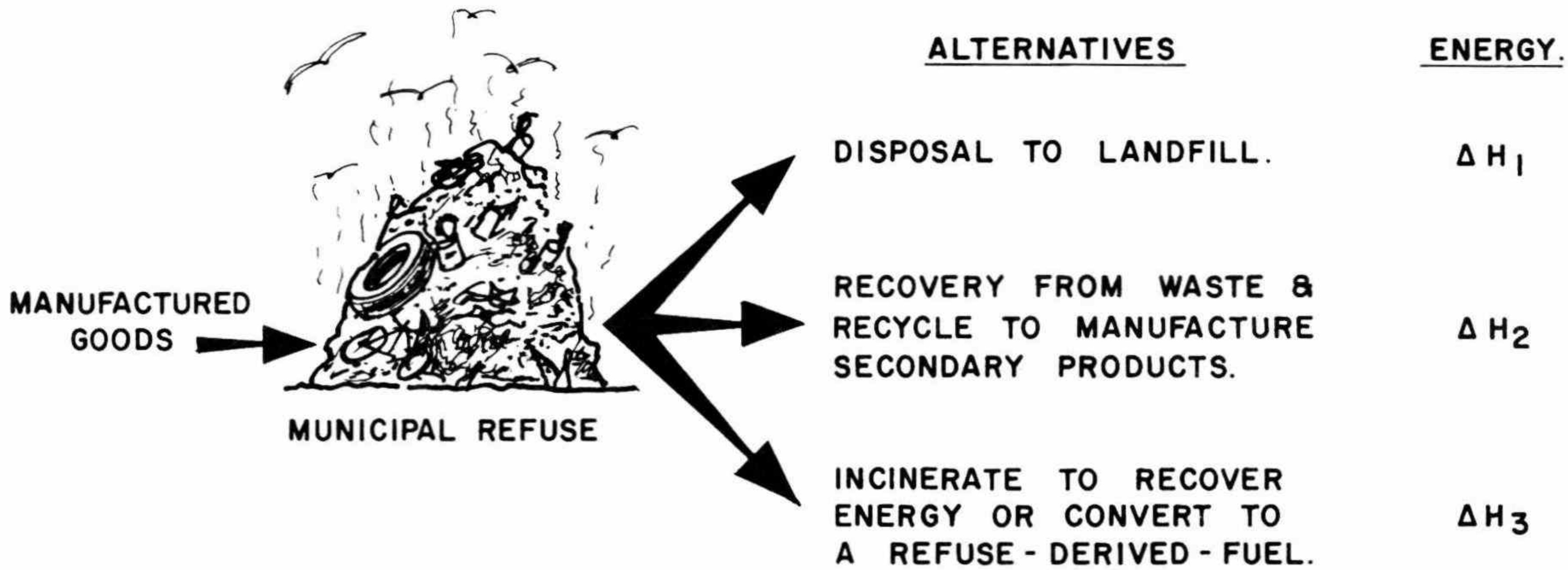
2. G. Winstanley, Energy Analysis Methods, Uses, Implications, Office of Energy Conservation, Department of Energy, Mines and Resources, Ottawa, Ontario, February, 1976. Office of Energy Conservation Research Series No. 11.

ACKNOWLEDGEMENTS

The study was sponsored by the Ministry of the Environment and the Ministry of Energy of Ontario as a part of the Province's Energy Management Program.

The work of Dr. F. J. Hopton, Dr. R. G. W. Laughlin and Mr. S. E. Sax of the Ontario Research Foundation is acknowledged with thanks.

RESOURCE RECOVERY OPTIONS



QUESTION : HOW DO ΔH_1, ΔH_2, AND ΔH_3 COMPARE ?

ANSWER : DO AN ENERGY ANALYSIS

FIGURE 1

METHODS OF ANALYSIS

PROCESS ANALYSIS	INPUT-OUTPUT ANALYSIS
- draw a process flowchart similar to a plant design.	- form a matrix of industrial inputs similar to that used for economic I/O analysis.
- follow the product from raw material acquisition through to the finished item and apply energy inputs at each stage.	- multiply matrices so that the total energy requirement of any commodity can be obtained by reading down the appropriate column of the matrix.
- no conversions necessary because all fuel inputs are measured directly.	- I/O economic tables are converted to energy by a Kwh/$ conversion.
- good method for detailed, highly specific answers.	- good method for quick, highly aggregated answers.
- use when obtaining G.E.R., N.E.R. P.E.R. or A.E.R. for a specific good or service eg. pineapples.	- use when obtaining G.E.R. for an entire industry eg. agriculture.

FIGURE 2

FLOWCHART OF A PROCESS ANALYSIS.

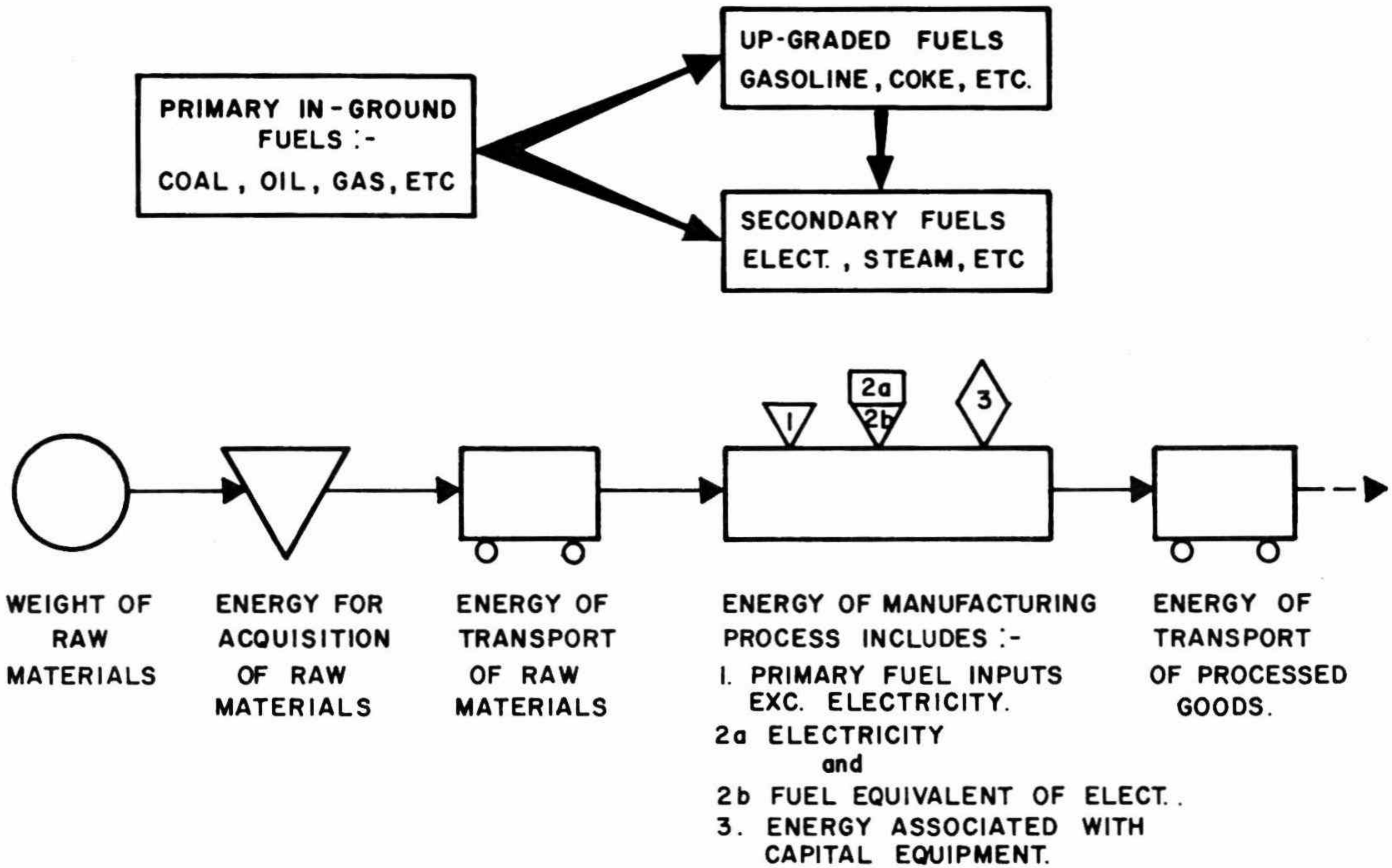
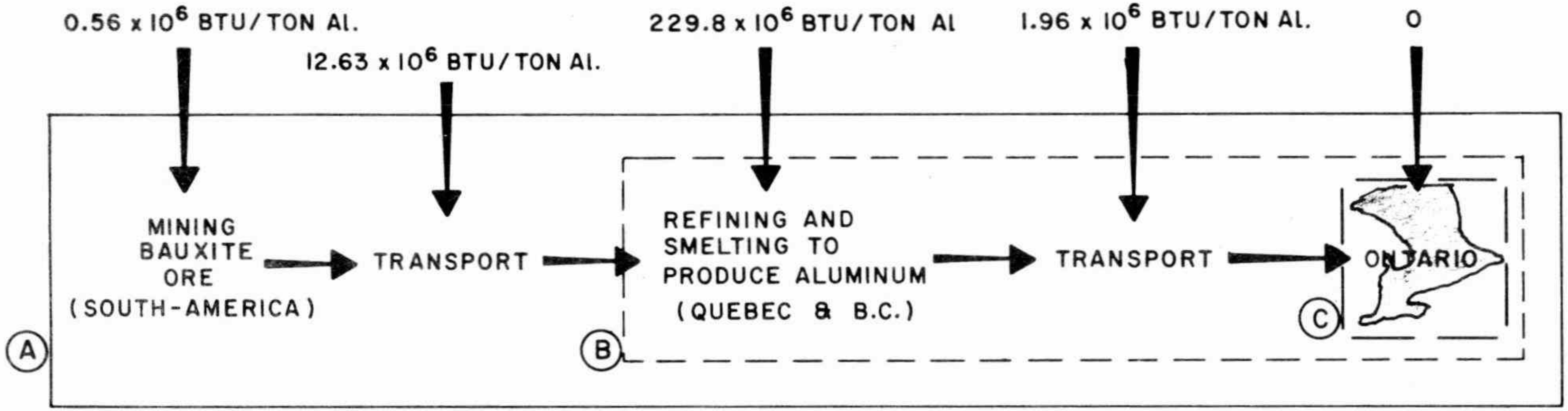


FIGURE 3

SYSTEM BOUNDARY FOR AN. N.E.R

CASE STUDY : ALUMINUM.

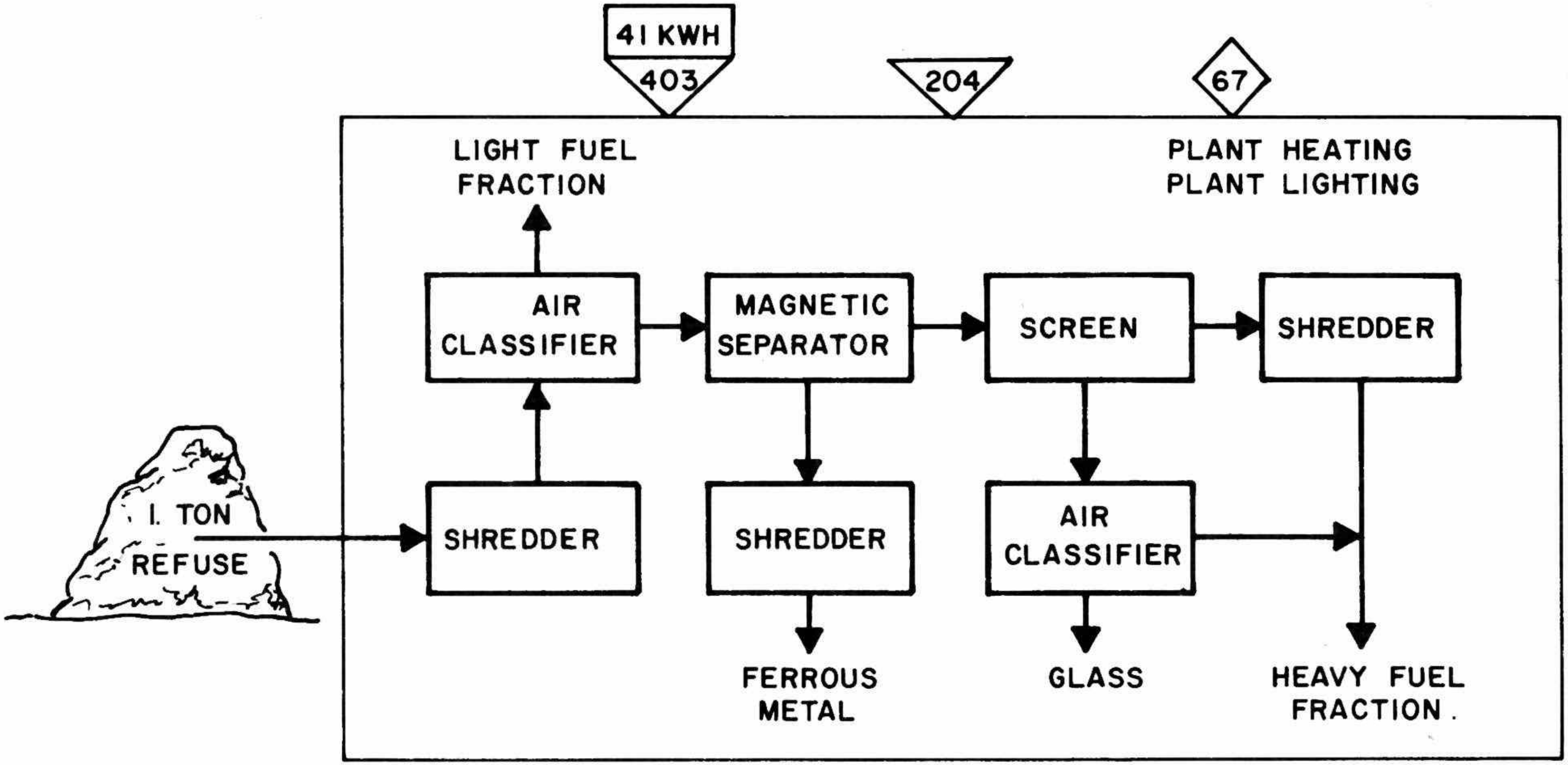


SYSTEM BOUNDARY		ENERGY / TON Al.
A	WORLD	244·95 BTU
B	CANADA	231·76 BTU
C	ONTARIO	0 BTU

FIGURE 4

ENERGY ANALYSIS OF RESOURCE RECOVERY CENTRE

(ENERGIES IN 10^3 BTU)

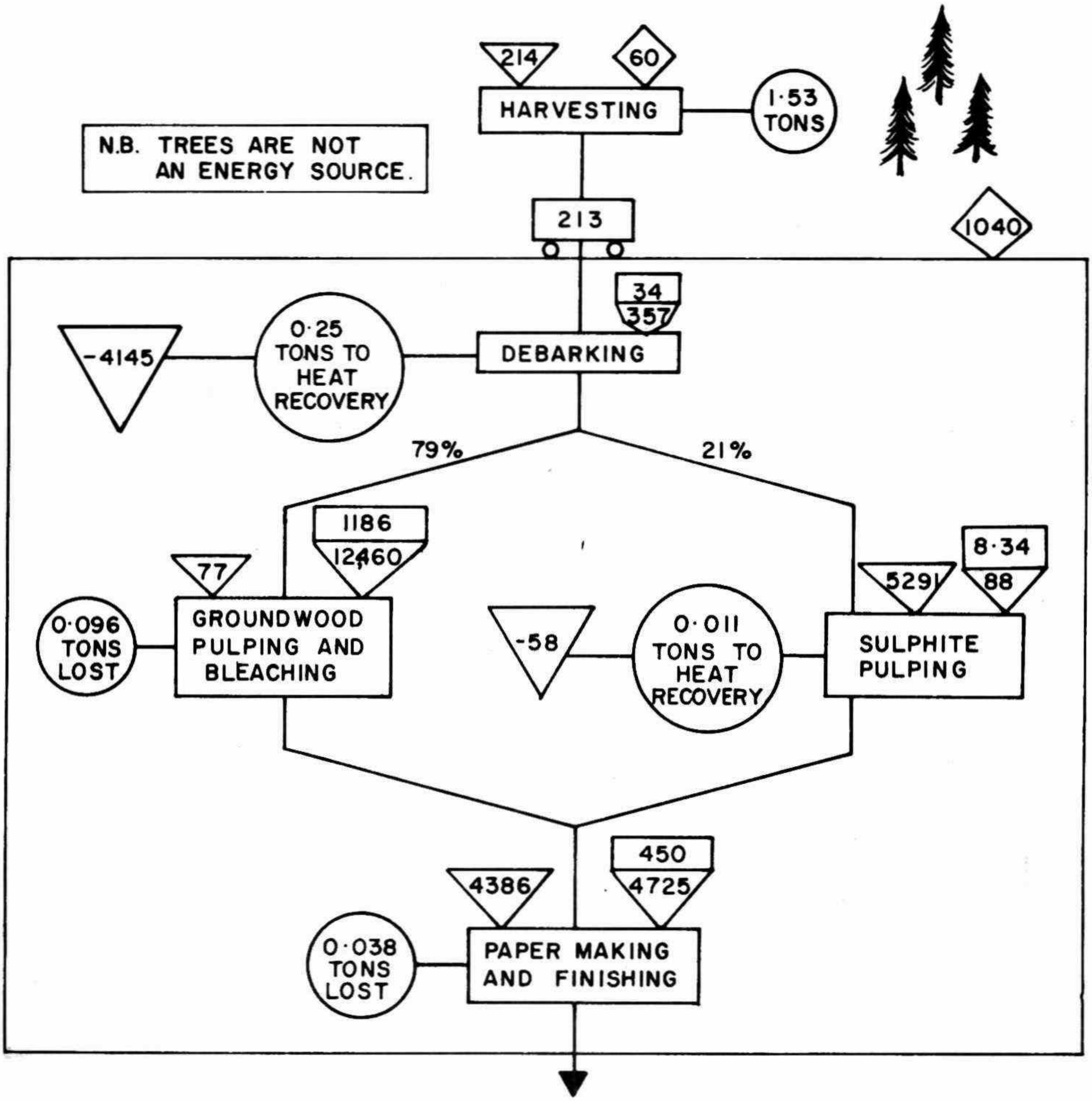


TOTAL ENERGY = 701×10^3 BTU / TON

FIGURE 5

ENERGY ANALYSIS OF NEWSPAPER PRODUCTION FROM TREES.

(ENERGIES IN 10^3 BTU)

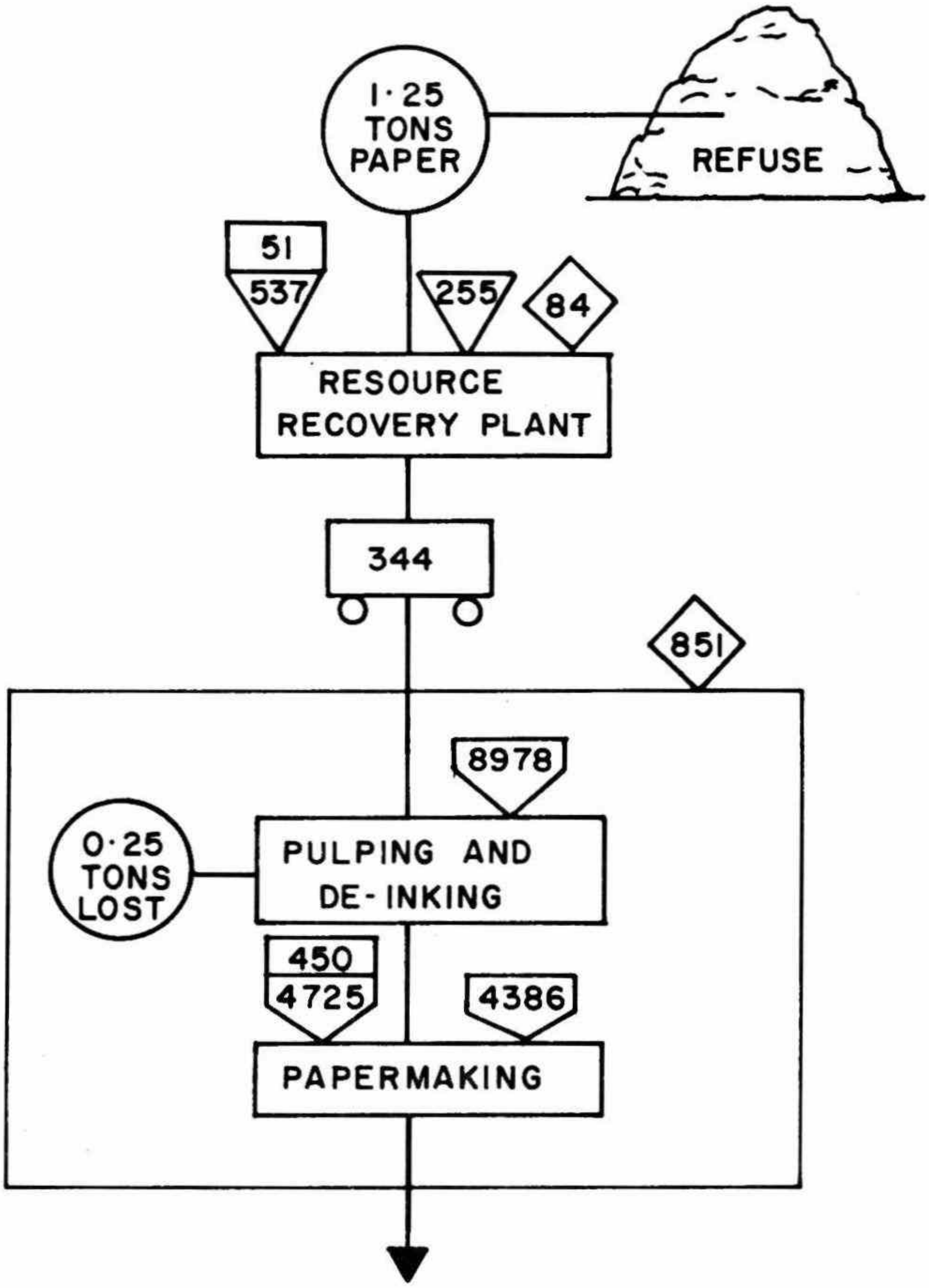


I TON PRIMARY NEWSPAPER
TOTAL ENERGY : 24,700 x 10^3 BTU / TON

FIGURE 6

ENERGY ANALYSIS OF RECYCLED NEWSPAPER

(ENERGIES IN 10^3 BTU)

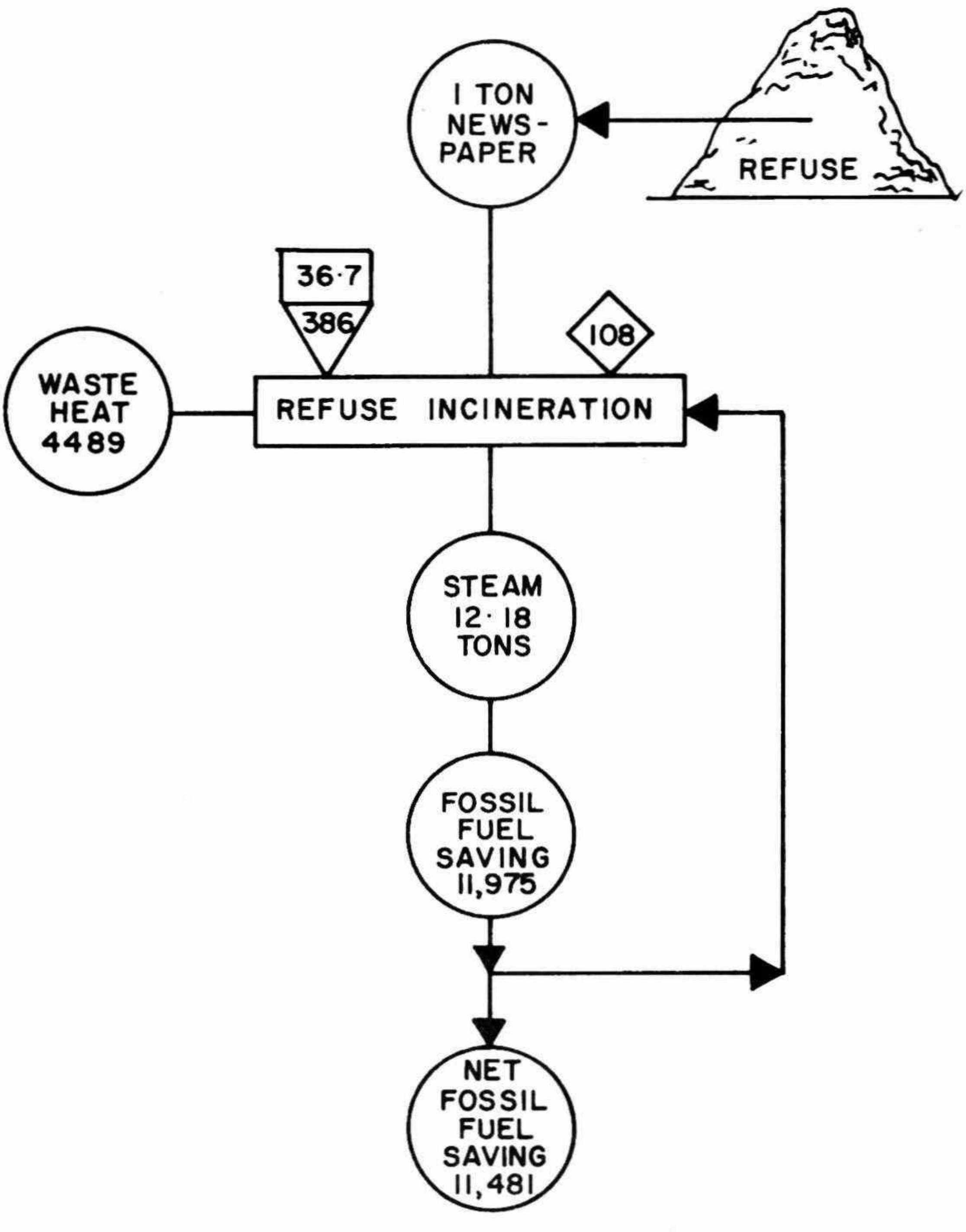


I TON SECONDARY NEWSPAPER
TOTAL ENERGY : = 20,160 x 10^3 BTU

FIGURE 7

ENERGY RECOVERY FROM PAPER INCINERATION

(ENERGIES IN 10^3 BTU)



$\therefore$ TOTAL ENERGY SAVING = 11,481 x 10^3 BTU

FIGURE 8

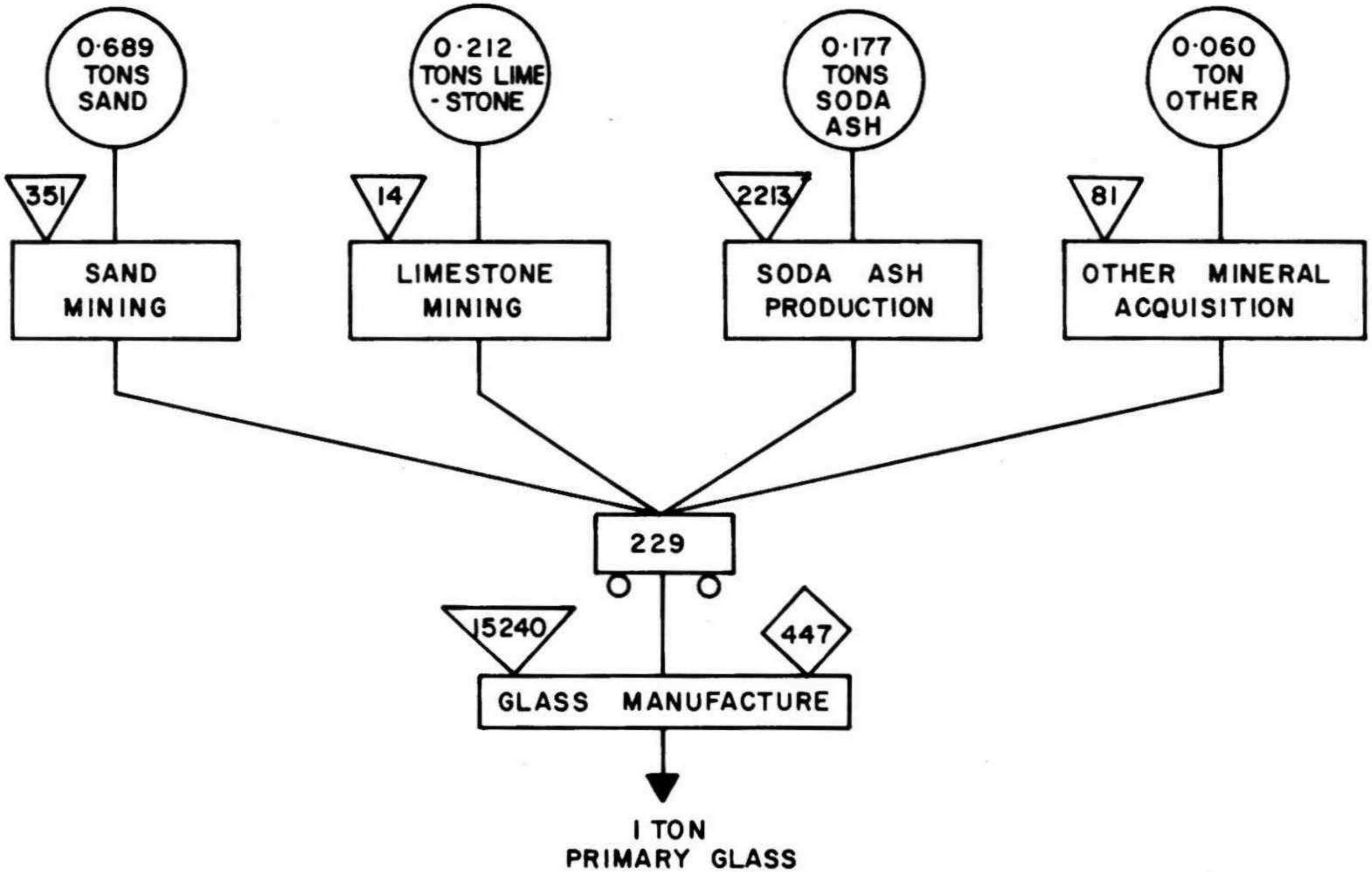
ENERGY RECOVERY EFFICIENCIES FOR NEWSPAPER

PROCESS	PRODUCT	NET FOSSIL FUEL SAVING PER TON NEWSPAPER
1. Incineration of unsegregated refuse.	Steam	11.48×10^6 BTU
2. Shredding, segregation and burning in a thermal generating station.	Electricity	13.18 "
3. Shredding, segregation and burning in a cement kiln.	Process Heat	13.91 "
4. Pyrolysis gasification and combustion.	Steam	10.74 "
5. Pyrolysis to fuel oil.	Heavy Fuel Oil	5.58 "
6. Slagging gasification and combustion.	Steam	13.14 "
7. Recycle to produce more newspaper.	Newspaper	3.62 "

FIGURE 9

ENERGY ANALYSIS OF GLASS PRODUCTION FROM SAND.

(ENERGIES IN 10^3 BTU)

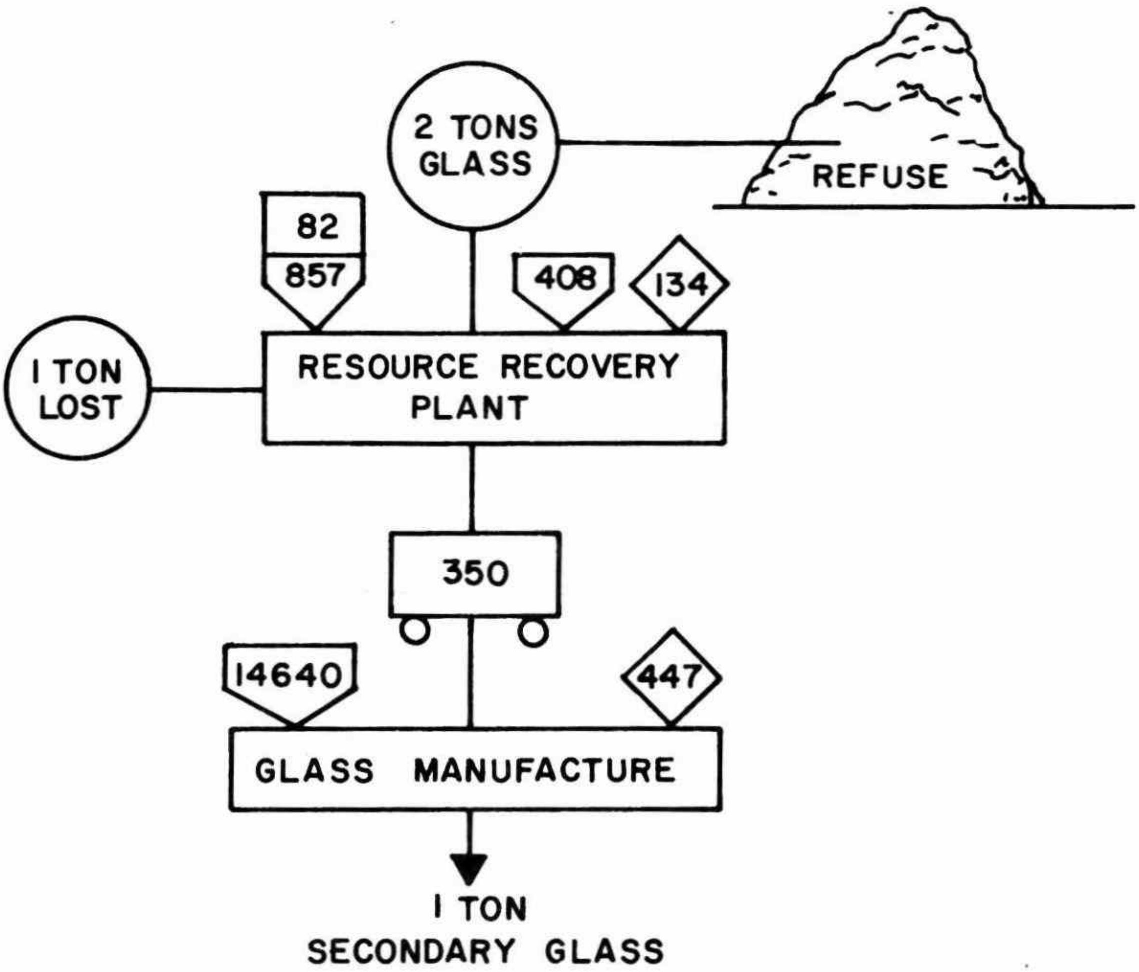


TOTAL ENERGY = 18,575 x 10^3 BTU

FIGURE 10

ENERGY ANALYSIS OF GLASS PRODUCTION FROM REFUSE.

(ENERGIES IN 10^3 BTU)

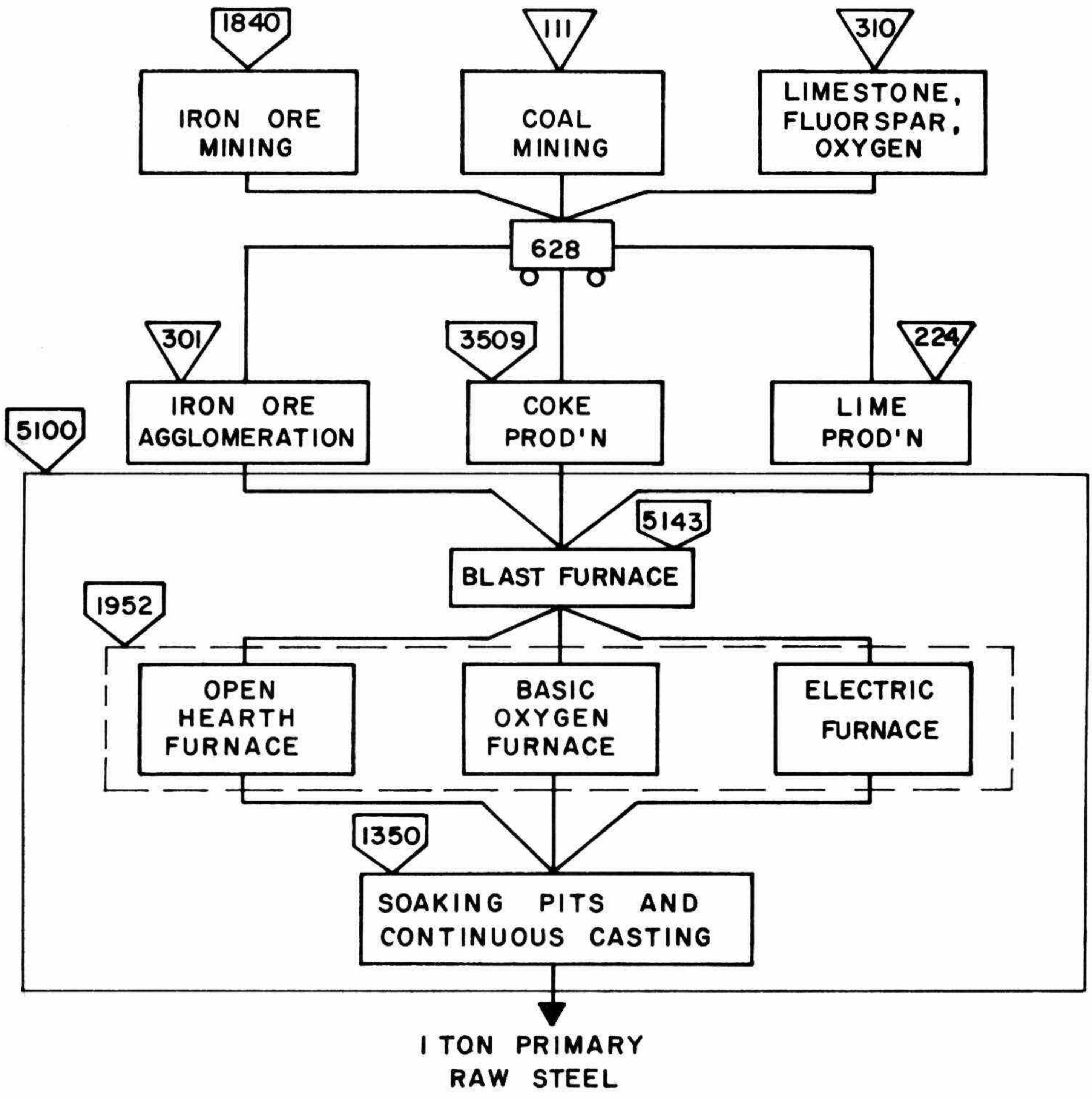


TOTAL ENERGY = 16,836 x 10^3 BTU

FIGURE 11

ENERGY ANALYSIS OF INTEGRATED STEELMAKING

(ENERGIES IN 10^3 BTU)

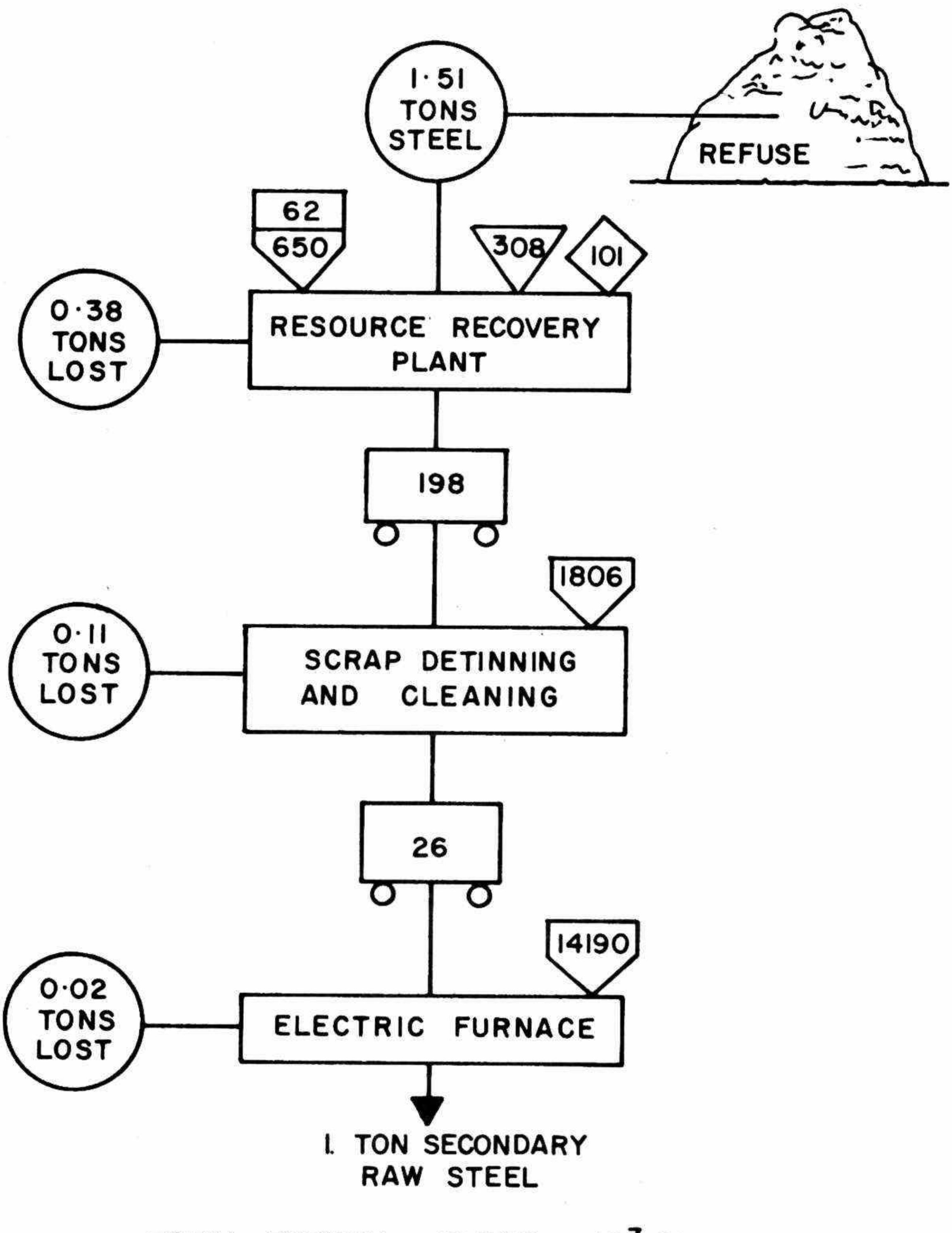


TOTAL ENERGY = $20,468 \times 10^3$ BTU

FIGURE 12

ENERGY ANALYSIS OF RECYCLED STEEL.

(ENERGIES IN 10^3 BTU)

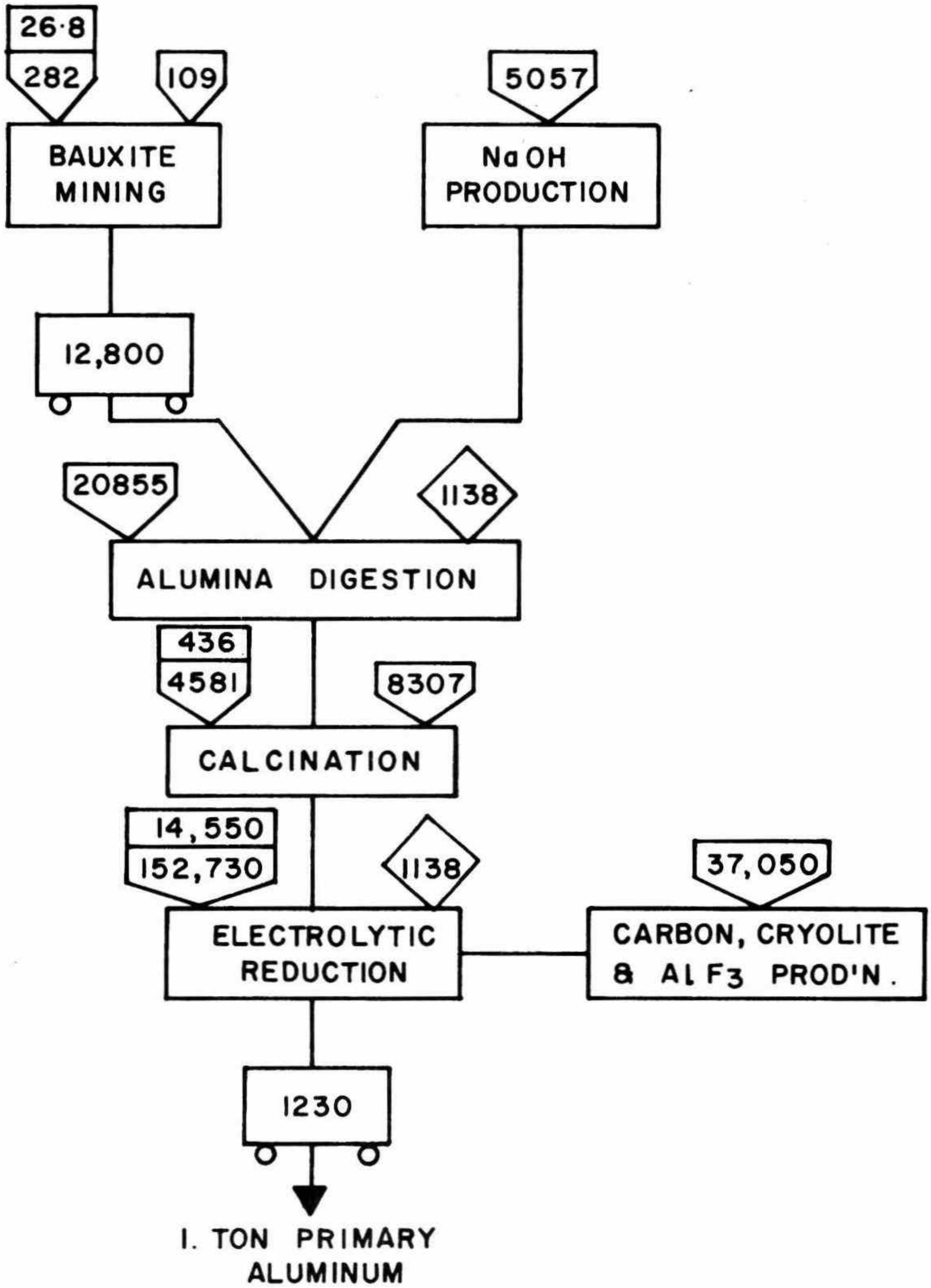


TOTAL ENERGY = 17,300 x 10^3 BTU

FIGURE 13

ENERGY ANALYSIS OF ALUMINUM PRODUCTION

(ENERGIES IN 10^3 BTU)

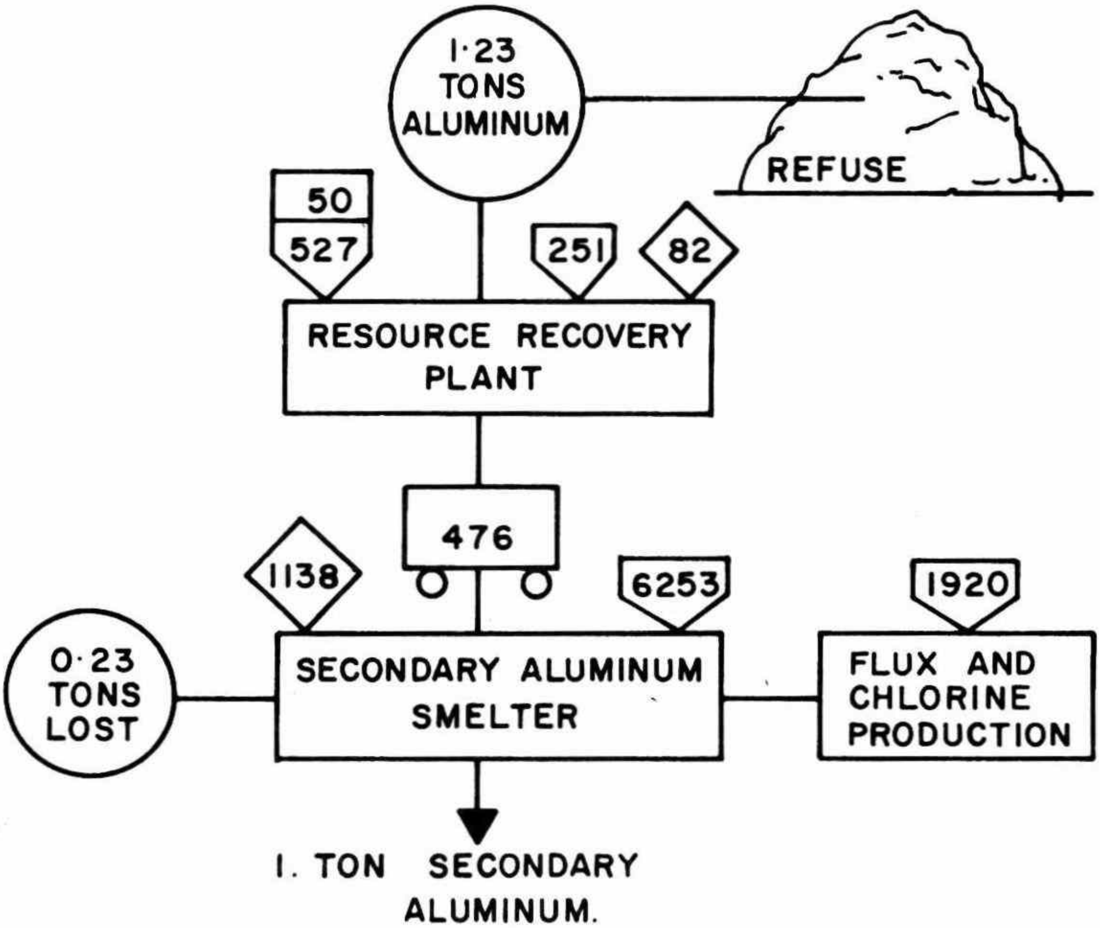


TOTAL ENERGY = 245,300 x 10^3 BTU

FIGURE 14

ENERGY ANALYSIS OF RECYCLED ALUMINUM

(ENERGIES IN 10^3 BTU)



TOTAL ENERGY = 10,647 x 10^3 BTU

FIGURE 15

SUMMARY

COMMODITY	ENERGY SAVINGS BY RECYCLING BTU/TON	ENERGY RECOVERED BY USING AS A FUEL (BTU/TON)
Newspaper	4.54×10^6	$5.6 - 13.9 \times 10^6$
Glass	1.74×10^6	N.A.
Steel	3.17×10^6	N.A.
Aluminum	234.7×10^6	N.A.

FIGURE 16

RENEWABLE ENERGY, SOCIETY AND THE ENVIRONMENT

At the present time in Canada, and generally throughout the world, a complex and inter-related tangle of problems is facing society; problems which have their origin in the energy sector. These problems may be economic, environmental, social or political in nature but they can be traced to a common source; our inability to meet ever increasing demands for energy without incurring major social difficulties. Viewed within a time frame of 20 years and beyond, and in the context of international developments, this energy related complex of problems appears likely to worsen unless substantially new patterns of energy production and consumption are developed.

One energy technology which holds promise for alleviating both energy shortages and environmental problems and which is described in this paper, is that of renewable energy, solar energy, wind power and energy from biomass materials including organic wastes. Contrary to a widely held perception, renewable energy technology is essentially "in hand" and could be rapidly applied to our energy problems. Certain institutional barriers remain to be overcome. Industry has a critical role to play in the large-scale development and dissemination of this technology.

by

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Dr. Macdonald obtained his degree in physics at the University of Toronto studying gas-phase chemical kinetics of interest in atmospheric chemistry and air pollution problems. Following further studies at Cambridge and the Centre for Research in Experimental Space Science, York University, he joined the Faculty of Environmental Studies at York, where he is currently involved in research and teaching on subjects related to energy, society and the environment. Dr. Macdonald is also an associate with Peter Middleton and Associates, Environmental Consultants.

RENEWABLE ENERGY, SOCIETY AND THE ENVIRONMENT

by

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The effective use of energy has been an important component in the economic and social development which has taken place in Canada over the last 100 years. During this period of time, the amount of energy that we as Canadians consume has steadily increased until, today, our per capita consumption of energy is second in the world only to that of the United States. Much of our vast and rapid economic growth has been predicated upon certain implicit assumptions about our energy resources. We have, in large measure, assumed that energy would always be available in the forms which we require, that it will be available in essentially unlimited quantities, inexpensively and at low social and environmental costs. Today, however, our nation is confronted by a serious predicament which challenges these traditional, implicit, assumptions about the use of energy, and in so doing, strikes at the very basis of our energy-dependent economic and social system. In short, the era in which our country, as well as the majority of the world's industrialized nations, developed and brought to fruition an immense and diversified economic system, an era characterized by inexpensive and readily available energy, is over.

The energy study recently released by the Federal Department of Energy, Mines and Resources, entitled "An Energy Strategy for Canadians: Policies for Self-Reliance" sets forth the complex dimensions of the energy dilemma which Canada is facing. Briefly, our demands for energy are continuing to rise at a time when existing, relatively inexpensive reserves of the energy forms on which we are almost totally dependant - petroleum, natural gas and hydroelectric power - are rapidly being depleted. New discoveries of oil and natural gas resources in the frontier regions of Canada, offshore in the Atlantic and the North, have been disappointing

to date. Those resources which have been found are located in regions so remote and environments so hostile as to present immense technical, economic and environmental difficulties in terms of producing and transporting them to market. Capital costs of energy production facilities such as electrical power stations, tar sands plants and coal production facilities are rising steeply to astronomical figures. Environmental problems are increasingly more severe as the scale of our energy-related activities increases and more energy resources are sought in ecologically vulnerable areas. Social and political issues relating to native land rights, provincial ownership of energy resources, the international movement of energy resources and the social implications of environmental impacts are all pressing to the fore of the energy decision-makers' list of priorities. In all, a complex of economic, technical, social and environmental problems, aggravated by the growing rate of our energy consumption and the huge magnitude of the amounts of energy presently being consumed in Canada, are combining to produce a situation in which our best efforts to supply energy in the near and the longer-term future will be inadequate to provide for the projected energy demands. This short-fall between supply and demand can possibly be met by importing energy from beyond our borders. However, this option carries with it economic and political risks which the Government of Canada rightly views with great concern. The problems associated with the recent OPEC petroleum embargo have vividly demonstrated the vulnerable position in which countries depending upon imported energy find themselves.

A variety of policies have been put forward in the Energy, Mines and Resources publication as possible means for addressing this problem. If the amount of money and effort to be invested in a particular energy sector is an indication of the importance which the Federal Government assigns to that particular sector, then very clearly the priorities and, hence, the major emphasis of federal policy during the next fifteen years will be concentrated upon strenuous attempts to increase

the supply of conventional energy forms, principally petroleum, natural gas and electricity generated by nuclear energy. Unfortunately, the information put forward in this report indicates that, except under the most favourable circumstances that might be expected, our ability to supply energy from our indigenous resources will fall increasingly below the projected business-as-usual demand for energy. For example, Canada today is a net importer of energy, principally in the form of petroleum. This dependency upon imported petroleum will increase in the years ahead and lead to a projected balance of payments deficit of several billion dollars by the mid 1980s. Only by assuming the availability of what are considered to be "low certainty" energy resources will Canada be able to regain a measure of self-sufficiency in total energy supply, in terms of conventional energy forms, by the year 1990. As the EM&R report states:

> It should be stressed again, that the reattainment of the net energy surplus position experienced in Canada from 1970-75 is subject to a number of uncertainties. That portion of anticipated energy supplies that is highly uncertain at the current time includes oil sands operations additional to those currently under way and frontier production. The rate and extent of developments in these areas will depend on environmental and social considerations, technological advances, the availability of manpower and equipment, the availability of financial capital, and - in the frontier areas - succuess in exploration activities. (EM&R report: page 86.)

The Inadequacy of Nuclear Energy

A notion which is widely held, both in government and in the private sector, is that nuclear energy will be able to provide for our growing energy demands as the supply of fossil fuels begins to fail. Unfortunately, this simply is not the case. An examination of the energy-use patterns in Ontario reveals the nature of the problem. To date, nuclear energy has been harnessed only for the production of electricity. In Ontario, today, nuclear generated electricity meets less than 5% of our total end-use demand for energy, with by far

the largest amount of energy consumed being in the form of oil and natural gas. To achieve the rapid transition to an all-electric society, at a rate sufficient to compensate for the projected short-fall in our fossil fuels, is simply impossible. To convert the existing capital equipment in the industrial, commercial and residential sectors from the use of oil and natural gas to electricity would be costly and time consuming. Moreover, there are many applications, such as in the transportation sector, where a change to electricity would be exceedingly difficult. Finally, and perhaps most importantly, the amount of capital and the rate of construction of electrical generating plants required to provide the necessary amounts of electricity clearly exceed the present capacity of our economy. The Minister of Energy for Ontario has publicly commented that capital constraints have made it impossible for nuclear generated electricity to compensate for fossil fuel shortfalls, in any large-scale manner.

I would like to comment here, briefly, on certain of the environmental consequences associated with the use of nuclear power. The generation of electricity by nuclear energy is often described as a clean source of power. So it is if we are narrowly concerned with those traditional forms of air pollution associated with fossil fuel burning generating stations; SO_2, NO_x, CO_2, particulates, etc. Nuclear power stations produce, however, waste products in the form of radioactive wastes, which are of a fundamentally different nature than these previously mentioned chemical air pollutants. Pound for pound, radioactive wastes are considered to be among the most dangerous substances ever to exist upon the surface of the earth. This is doubly so because, unlike chemical pollutants which often can be rendered harmless relatively quickly and easily by a variety of technical or natural processes, these nuclear wastes remain dangerously radioactive for, in some cases, periods of time in excess of a quarter of a million years. No practical techniques known

to man, today, can render non-radioactive a substance once it has been made radioactive.† In demonstrating that nuclear energy is an acceptable form of energy, an urgent requirement facing the nuclear industry is that of showing that there exists a way of absolutely separating these wastes from the biosphere for periods of time stretching into the future far longer than civilization has existed in the past. Many reputable authorities consider that this requirement facing society in its use of nuclear energy, coupled with additional severe problems of safety, the nature of the possible consequences attendant to a major release of radioactive wastes from a power plant either as a result of an accident or because of deliberate sabotage, as well as the potential for the misuse of nuclear materials (such as India's exploding of an atomic bomb fabricated from nuclear materials produced in a Canadian reactor) are so grave as to call into question the social acceptability of a nuclear energy power program. In the United States, a virtual moratorium has been declared upon the construction of nuclear reactors for the generation of electricity. The debate on this subject is only just beginning in Canada.

An Alternate Energy Strategy

The costs of the proposed energy strategy, with its emphasis on conventional energy resources, a program which has been labelled as a "strength through exhaustion" approach, will be immense. To produce and deliver conventional energy supplies over the next fifteen year period could require energy-related investments of as much as $180 billion. Such an investment will inevitably require difficult trade-offs among the other sectors of Canada's socio-economic system. Faced with the imminent possibility of this program, an exceedingly relevant question which we might ask is the following: Will the proposed outpouring of resources, effort and time, to be spent during the next fifteen years, result in the achievement of the desired objective, namely, a more satisfactory and secure energy position in Canada? Given

† Only the passing of a sufficient amount of time, which differs from one form of nuclear waste product to another, results in the reduction of this radioactivity.

the present allocation of national resources, I believe that the answer to this question is no. The evidence put forward in the EM&R study indicates that the proposed strategy, with its emphasis upon conventional energy forms, can only lead to a situation in fifteen years in which we will still find ourselves to be a country largely dependent upon petroleum and natural gas. Moreover, we will be consuming these fossil fuels at twice the 1970 rate and, although the graphs of the EM&R study halt, tantalizingly, at 1990, our fossil fuel resource base will certainly be much closer to exhaustion than is the situation today. In other words, the proposed allocation of resources will not solve our energy dilemma. Rather, an even more precarious position for the nation will result. We must recognize today that the fossil fuel era, at least in terms of petroleum and natural gas, is essentially over.

The critical question then becomes: Are there alternate ways of investing the country's resources which might both effectively address our country's energy dilemma and lead to a more desirable energy position in the future than the proposed strategy? The answer to this question, I believe, is yes. The undertaking of an effective energy conservation program and the rapid and large-scale development of Canada's so-called renewable energy resources, are two components of an alternate energy strategy which I believe would accomplish these two ends.* Both energy conservation and research into renewable energy technologies are discussed in the EM&R study.

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* The details as to how a transition might most effectively, with the minimum number of dislocations, be made from our fossil fuel/nuclear electric energy economy to an energy conservation/renewable energy economy, are impossible to deal with here. It is worth noting that coal, a non-renewable fossil fuel of which we have exceedingly large resources, combined with recent developments in environmentally "clean" combustion technology, might serve as a fossil fuel "bridge" to assist us in moving from our current dependency upon oil and natural gas over to a largely renewable energy future.

However, by comparison with the projected huge investments in conventional forms of energy, they are receiving only token and totally inadequate federal support.

It is impossible, in this paper, to describe the immense potential that exists for addressing Canada's energy dilemma through energy conservation means. This country, like most industrial nations, wastes fully one-half of all the energy it consumes. A large number of recent studies have clearly indicated that by far the most cost-effective way of essentially increasing our energy resources is to stop wasting energy.† Dollar for dollar, effort invested in energy conservation almost always results in substantially more energy being made available to society than similar investments in the development of new energy resources. To a very large extent, conservation is a "panacea" which could substantially reduce the projected shortfalls in energy without adversely affecting our economy and our environment. The energy conservation studies to which I referred have indicated that there is an important potential for industry, not only in terms of implementing conservation measures in-house but also in terms of the large market for new energy conservation technologies and products. I would like to emphasize that, in the alternate energy strategy which we are considering, effective energy conservation measures are the vital prerequisite for the successful development and implementation of renewable energy technologies.

The concern is sometimes expressed that a widespread program of energy conservation could lead to adverse effects upon our economy. To hold this view is to confuse energy conservation with energy curtailment. Serious economic problems will not arise from a reduction in the amount of energy we waste. On the contrary, energy conservation is more likely to stimulate our economy than to adversely affect it. Serious economic consequences may well arise if, through failure to achieve effective conservation measures, widespread energy shortages develop and enforced curtailment of energy use results.

† See, for example, "A Time To Choose: America's Energy Future" by the Energy Policy Project of the Ford Foundation (1974). Ballinger Publishing Co.

The Nature of Renewable Energy

What is the nature of our renewable energy resources? We are all familiar with our non-renewable energy forms such as oil, natural gas, coal and uranium, all of which exist in the earth's crust in finite amounts. As we have discussed, it is the imminent exhaustion of oil and natural gas which presents Canada with its energy dilemma. By contrast, renewable energy resources are, to all intents and purposes, inexhaustible, depending as many of them do upon the sun as their ultimate source of power. Renewable energy forms include, therefore, solar energy, directly in the form of light and heat from the sun, and indirectly in such forms as wind energy, wave energy and the energy of biomass. This latter energy form refers to the chemical energy locked within organic plant and animal materials, energy derived from the sun through the process of photosynthesis. A form of renewable energy which we are currently harnessing is hydroelectric power, which today provides Canada with nearly 25% of its primary energy needs. Two other forms of renewable energy which are not directly related to solar power, tidal power and geothermal energy, hold considerable promise for certain regions of Canada. In addition to their inexhaustible nature, the harnessing of our renewable energy resources, especially solar and wind energy, will have far fewer undesirable environmental consequences than is the case for fossil fuels or nuclear energy.

There are a number of misperceptions about the potential which renewable energy resources have for contributing to Canada's energy needs. I would like to examine a number of these misperceptions or 'myths' and discuss some results of recent research on the potential for renewable energy in Canada.

Myth #1: Canada does not have significant resources of renewable energy.

Fact: A recent study undertaken for Energy, Mines and Resources by Peter Middleton and Associates† to assess Canada's renewable energy potential indicates that this country is in

† "Canada's Renewable Energy Resources: An Assessment of Potential" by Peter Middleton and Associates, Toronto (1976).

the fortunate position of having a substantial renewable energy resource base which, if combined with effective energy conservation measures and essentially existing technology, could meet the majority of our energy needs. For example, the Middleton study indicates that in almost all locations throughout the most populous regions of the country, solar energy could provide up to 100% of the space and water heating needs of the residential sector of our energy economy. About 20% of all the energy consumed in Canada is employed in this sector to provide low-grade heat, a form of energy which solar energy is admirably suited to provide. Similar needs for low grade heat in the commercial and industrial sectors could also be met by solar energy. In fact, it has been estimated that about 50% of all end-use applications of energy in this country are for low-grade heat, at temperatures below $150^{o}C$, which are attainable with the most recent designs of solar energy collectors.

About 25% of all our primary energy needs in Canada are currently being met by hydroelectric power, a form of renewable energy. It has been argued that by implementing effective conservation measures and by restricting the use of electricity to those relatively few applications which absolutely require this high-grade form of energy - applications such as lighting, electronics, electrochemical processes and so on - much of our electrical energy need could be met with our existing hydroelectric power resources. There simply would not be a need for the huge nuclear electric power program which is presently being initiated. Coal and biomass materials, such as wood, could be used for the production of electricity to augment our hydro electric resources, where necessary.

Additional amounts of electricity could be generated using wind power in those regions of Canada which possess favourable wind regimes. The province of Prince Edward Island, which currently depends almost entirely upon OPEC petroleum for its energy well-being, is seriously examining the possibility of using large wind turbines to drive electrical generators to produce substantial amounts of electricity for the electrical grid system in that province. The favourable, high-speed wind regime of Prince Edward Island, combined with the fact that the

current costs of petroleum-generated electricity are exceedingly high, have produced a situation in which electricity generated from the wind appears highly attractive.†

About 25% of our total end-use energy is required in the form of high-grade energy by the transportation sector, almost totally in the form of petroleum products. Industrial methanol, produced from biomass materials including wood, crop wastes or indeed organic wastes of any nature, appears to offer one of the few attractive possibilities for powering our transportation sector in a post-petroleum era. Canada has an immense land area, much of which is heavily forested. This large, per capita, biomass resource, if properly managed, could provide us with a substantial proportion of our high-grade fuel needs.

We have touched upon only a few examples which illustrate the huge potential for renewable energy resources. The evidence that is now available clearly indicates, by a proper matching of our energy needs with the appropriate renewable energy resource, that a major portion of all our energy requirements could be met from renewable energy resources.*

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* An important consideration in the future use of energy will be the careful matching of the energy form to the particular requirements of the end-use application. For example, from the point of view of extracting the maximum amount of benefit from the energy resource, it is wasteful to burn oil or natural gas at temperatures in excess of 1000°F to heat a house which requires temperatures of 70°F. There exists, in this example, a clear mismatch between the energy form used and the end-use application. Another such example is the use of high-grade electrical energy for the heating of houses. Such low temperature applications would much more efficiently be met using a low-grade energy form, such as is obtainable from existing designs of solar collectors.

† In addition to PEI, large areas of the Atlantic Provinces, the Prairies and British Columbia, and some parts of Quebec and Ontario, appear to have wind regimes appropriate for the generation of electricity from wind power. Relatively high winds are found off-shore in Lake Ontario and Lake Erie. Perhaps, in the future, numbers of large wind turbine electrical generators will be mounted on floats and moored some distance off-shore on the Great Lakes, with the electricity produced being transported to shore by underwater cable.

Myth #2: Renewable energy technology is either not developed or still highly experimental.

Fact: While research continues in many areas of renewable energy technology, as might be expected in the case of any rapidly developing modern technology, many forms of renewable energy technology are well in hand and are currently being manufactured, for commercial sale, in the United States, Canada, and elsewhere throughout the world. In the case of certain other renewable energy technologies, the major developmental problems facing these technologies are of an engineering, not of a fundamental research nature. For example, the parliamentary secretary to the Minister of State for Urban Affairs recently commented as follows with regard to the use of solar energy in housing:

> There is no problem regarding the means of utilizing the heat of the sun for heating homes and providing other forms of energy. Solar homes have already been successfully built, and the essential technology for collecting, storing and distributing the sun's energies is already in place. Refinements and improvements are yet to come, of course, but the essential fact is that we know right now how to use solar energy in a practical way. The major problem, then, is not a technical one. The real challenge is to increase public awareness of the potential of solar energy and to make its advantages available as quickly as possible for housing throughout Canada.†

Canada, in a small way, has already assumed a world leadership role in the development and marketing of certain renewable energy technologies. In Toronto, Dominion Aluminum Fabricating Company, in collaboration with NRC, has developed and is marketing a "high speed, vertical-axis, wind turbine" for producing electricity, in a variety of sizes ranging from a 3 kilowatt device to a 200 kilowatt turbine. This latter device which is presently being installed by Hydro Québec on the Magdalene Islands, in the Gulf of St. Lawrence, is the wind generator which the Government of Prince Edward Island is currently examining. The technology for storing solar energy gathered during the hot days of summer, for subsequent

† Notes for Remarks by Jean-Robert Gauthier, MP, to the Canadian Association of Housing & Renewal Officials, Edmonton, Alberta. (May 4, 1976)

use in winter, thereby providing up to 100% of a residence's space heating requirements, has been pioneered by Professor Frank Hooper of the University of Toronto and is now being marketed by his company, Envirogetics.

In the area of biomass energy, the utilization of wood wastes by pulp and paper companies, the development by CIL of techniques for the gasification of organic materials and such projects as the "Watts From Waste" program in Toronto are evidence of industry's growing awareness of the potential for activity in this area of renewable energy technology.

In addition to the examples mentioned, there are a number of companies throughout Canada which are either manufacturing or importing renewable energy technology. However, the scale of this industrial and commercial activity remains very small when compared to the immense size of the potential market and the pressing need for the development of our renewable energy resources.

Myth #3: The economics of renewable energy technology are unfavourable.

Fact: Today, in Canada, to heat a home by solar energy or to provide its electricity by means of a wind-powered generator, would be expensive. It would, however, be a mistake to confuse these present costs, for what are essentially hand built, experimental prototypes, with the costs to which we can confidently look forward under a mass-production situation. We are, today, in the very early stages of a process of technological innovation. The costs of renewable energy technology will remain relatively expensive until the full advantages of economies-of-scale through mass production and modern industrial fabrication, distribution and installation techniques are realized.† Nevertheless, in many situations in the United States and elsewhere in the world, at the present time, renewable energy technology can perform as cheaply as or more cheaply than existing conventional energy technology and does so in a manner unaffected by the rising costs associated with conventional

† The extremely comprehensive ERDA (Energy Research & Development Agency) program in the US has, as its objective, the achievement of this mass-marketing/cost reduction situation.

energy forms. The Middleton study indicated that by 1979, making reasonable assumptions about the economies-of-scale which should have been achieved by that time, solar space heating will be economically competitive with electrical heating anywhere in Canada and will be competitive with oil heating in those areas of Canada characterized by long, cold winters with clear, sunny skies.†

We have already indicated that the high cost of electricity produced from petroleum in the Maritimes has lead to a situation in which it would appear that electrical energy produced by large wind powered generators may well be competitive with electricity produced by conventional energy sources.

Thus, while in 1976, we have a situation in Canada where renewable energy technology is relatively expensive, the very large efforts in the United States and elsewhere, directed towards achieving the commercial development of renewable energy technology, hold out the promise of a substantial reduction in the costs of these forms of technology in the near future.

Myth #4: The market for renewable energy technology is not a significant one.

Fact: An examination of current Canadian energy-use patterns reveals the huge potential market for renewable energy technology. In Canada there are presently about 7 million dwelling units, all of which must be heated. It is projected that an additional 3 million units will be constructed by the year 1990. From the point of view of our alternate energy strategy, it is imperative that these homes be built to the highest energy conservation standards. The addition of $400 to $1000 to the initial capital cost of these buildings could reduce their space heating needs by a factor of 50% as compared to existing housing. Solar space heating could economically and technically supply much of the remaining space heating energy requirements. The potential new industry required to equip these 3 million new units, as well as to "retrofit" existing buildings with solar space heating equipment, is but one example of the immense economic possibilities presented by a

† In comparing the costs of renewable energy systems with conventional energy systems, the Middleton study employed a form of life-cycle costing called the 'user-cost' method.

transition from conventional energy technology to renewable energy technology. Applications for solar energy technology exist in both the industrial and commercial sectors where low-grade heat energy is required. In the United States, it has been estimated that by the year 2000, today's tiny solar energy industry may have developed into a $25 billion a year giant, roughly equivalent in size to North America's present electrical machinery industry.

In a similar manner, a large potential market exists for renewable energy technology using wind energy or the energy derivable from biomass, in a variety of end-use applications throughout our energy economy. Already today, we see considerable efforts being devoted towards utilizing wastes for the production of useful energy. The "Watts From Waste Program" of Metro Toronto, in collaboration with Ontario Hydro is an example. Increasingly the pulp and paper industry is making use of the large amounts of wood wastes produced in their operations for the generation of both electricity and process heat. A number of large chemical companies are presently investigating the potential for the conversion of biomass materials into low BTU gas for industrial applications or for upgrading into methane or methanol.

Institutional Barriers

The evidence which we have discussed strongly suggests that renewable energy resources can contribute significantly to Canada's energy needs. However, to do so in the short time frame facing us, appropriate technologies must be combined with energy conserving strategies and diffused rapidly, on a large scale, throughout a large and diverse array of energy end-use applications. In achieving this objective of rapid development and diffusion, the Canadian industrial and commercial sectors have a critical role to play. However, before such a process of rapid diffusion can take place, there are a number of basic institutional problems which must be addressed. In short, the existence of a national need in the

energy sector does not necessarily result in the automatic existence of a national market for renewable energy technology, and in turn, it may well be that without being able to perceive a potential market, the industrial and commercial sectors cannot begin to put the existing results of research and development activity on renewable energy technology to work in the form of new products, processes and services for the public.

A prerequisite for the successful introduction of renewable energy technology into the marketplace is that a number of different institutions, including industry, must focus their attention and activity upon renewable energy technology and begin to work together successfully to create those conditions conducive to the rapid diffusion of this technology. A considerable amount of study, especially in the United States and recently at York University, has been given to this problem of how to bring about rapid, substantial innovation within society. The concept of a "Technology Delivery System" (TDS) has been employed to represent the complex processes by which a technical innovation can be introduced into the marketplace in the form of a new product. Figure 1, which is adapted from an article by Arthur A. Ezra[†], outlines a possible TDS for the diffusion of solar space heating into the private housing market.

A number of key institutional "actors" are identified in this model: 1. research and development performing institutions such as universities, non-profit research institutions and small R&D performing research companies. 2. industrial and commercial institutions which manufacture and sell the products based upon the new technology. 3. lending institutions which play an important role in making funds available for the manufacture or the purchase of the products. 4. government, both provincial and federal, whose ability to apply a variety of incentives at a number of points in the TDS is critical in facilitating the interaction of the component institutions.

† "Technology Utilization: Incentives and Solar Energy" by Arthur A. Ezra: Science, Volume 187, 28 February 1975.

Before a new technology can reach the marketplace, in the form of a new product, on any significant scale, all of the components of the TDS must be in place and ready to accept it. A major institutional problem facing the implementation of renewable energy technology is that of bringing about this state of readiness. When a TDS does not exist, as is clearly the case for renewable energy technology in Canada today, then it must be deliberately created. Government involvement is critical in this creation of a TDS if the rapid diffusion of renewable energy technology is desired. The present level of activity of government in the area of renewable energy is inadequate to achieve this goal.

It is essential that industry begin to play a much more active role in the development and diffusion of renewable energy technology. To date, only the most tentative involvement by industry in this technology exists and an immense amount of work must be done throughout Canada in developing the industrial component of the TDS.

There is much that industry can do, but two initial steps are critical. First, an educational process must be undertaken. Corporate executives and product managers must become aware of the potential that exists in all areas of our economic system for renewable energy technology. Secondly, there is the process of informing government that you, as an industry, are interested in this technology and wish to participate in its development. An active lobby by industry for support in the development of renewable energy technology would be an exceedingly effective vehicle for assisting in its rapid diffusion.

I would like to emphasize the importance of Canadian research and development initiatives in the area of renewable energy technology, as opposed to the situation which often prevails of simply allowing the innovation and the product distribution system to enter Canada from abroad. The technologies presently being developed in the United States and

elsewhere are not necessarily appropriate for Canadian requirements. Our climate and our energy needs are different than in the U.S. More importantly, Canada currently enjoys a world leadership role in the development of certain renewable energy technologies. If Canadian industry, as well as the other components of the TDS, does not awaken to the exciting possibilities associated with the huge potential for conservation and of renewable energy technology, we may well be missing out, both as an industry and as a nation.

Conclusions

It is generally conceded by energy researchers and by Canadian policy makers that, as our fossil fuels run out, we will be forced to rely on our essentially limitless renewable energy resources. However, the current perspective of the federal and the provincial governments (with the important exception of the Government of Prince Edward Island) is that "the development of such alternative energy sources can contribute relatively little in terms of total energy supply over the next fifteen years"†. While this may or may not be the situation, it is certainly true that no comprehensive study has been undertaken to substantiate this statement or to examine in detail what indeed might be the contribution of renewable energy resources to our total energy supply if they were the focus of a major effort comparable to that presently under way in the development of new oil and gas resources. If you recall, the federal government has projected investments of $180 billion during the next fifteen years in our continued development of conventional energy resources. By comparison, in 1975-76, research expenditures by the federal government on all renewable energy resources (hydro and tidal, solar, wind, geothermal and biomass), were $1.6 millions with an additional $1.0 million being budgeted for 1976-77. Moreover, it must be expected that during the

† EM&R Report: "An Energy Strategy for Canada", p.4

The importance of an immediate commitment to a serious renewable energy program is underscored by the observation that, historically, about thirty to fifty years have been required to bring about the transition of our country's energy system from a major dependency upon one form of energy over to a different energy form. The existing shortages of petroleum suggest that serious energy conservation efforts and the development of our renewable energy resources ought to have begun at least a decade ago.

In summary, a difficult decision regarding the nature of energy-use patterns faces Canada and the industrialized nations of the world. This decision is of fundamental importance to our social and economic well-being. One possible energy strategy which is open to Canada would involve the dedicated pursuit of energy conservation and the rapid development of renewable energy technology. This course of action would be directed towards achieving a transition of our energy economy away from a dependency upon fossil fuels to a renewable energy resource base. A second possible energy strategy would concentrate the majority of its efforts on a continued search for new resources of fossil fuels and the construction of nuclear power plants. This second course of action would thereby increase our existing dependency upon these conventional energy forms. The consequences for Canada and the position in which we will find ourselves, in thirty years, are fundamentally different, depending upon which energy strategy is undertaken. A pursuit of the second strategy would, in all likelihood, preclude any serious pursuit of the first.

I believe that the available evidence, when carefully and comprehensively weighed, within the time perspective of the next three decades, points to the energy conservation/renewable energy strategy as being the more desirable. Without the wholehearted support and involvement of the manufacturing and commercial sectors of our nation in the development, large-scale production and distribution of the necessary technology, the achievement of this desirable energy strategy will not be possible.

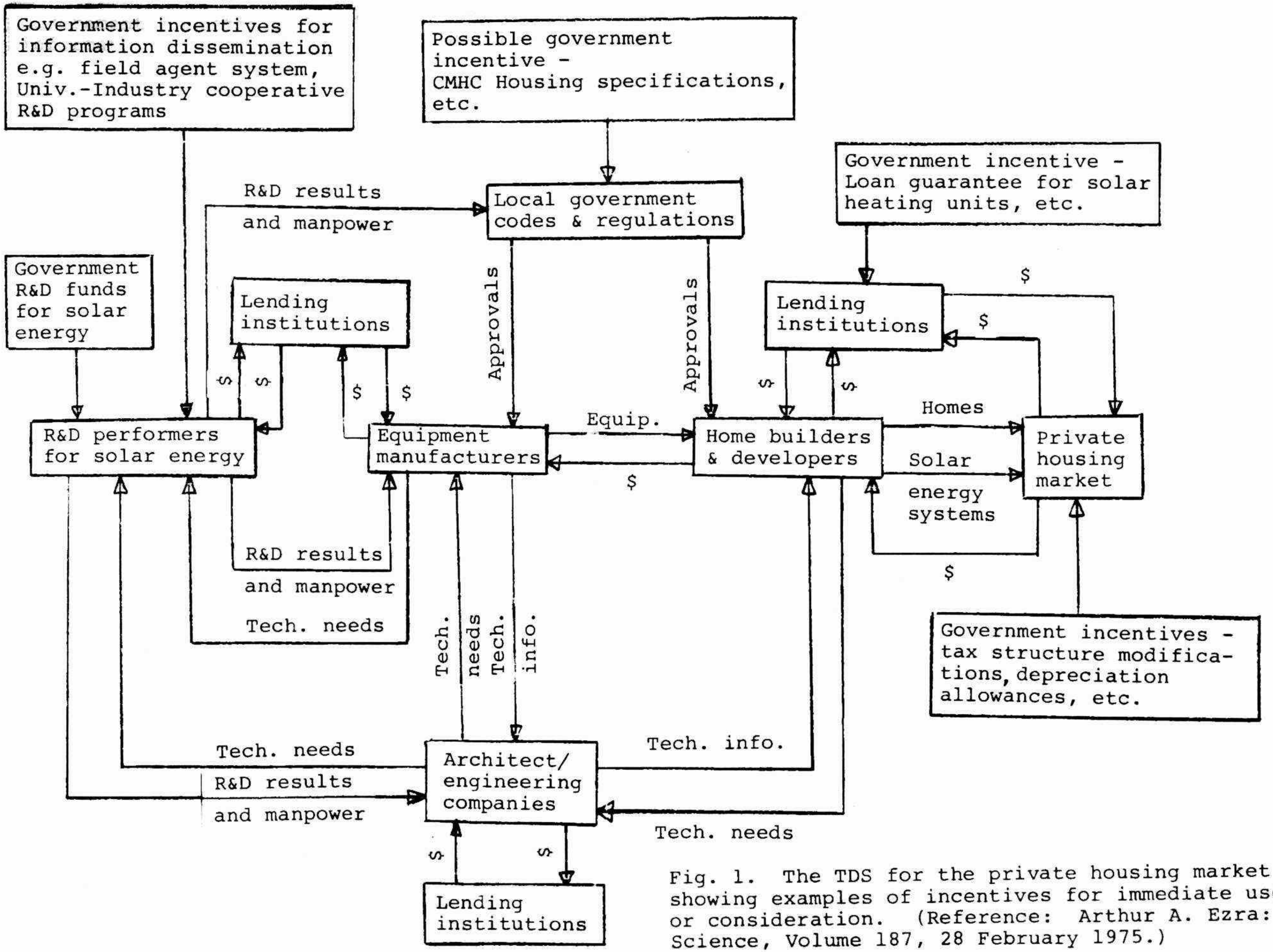

Fig. 1. The TDS for the private housing market showing examples of incentives for immediate use or consideration. (Reference: Arthur A. Ezra: Science, Volume 187, 28 February 1975.)

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WOOD WASTES TO ENERGY

A CENTRAL FACILITY FOR A TOWN IN NORTHERN ONTARIO

Wood waste in the area of Hearst, a small town in northern Ontario with five sawmills and a plywood plant located within a thirty mile radius, is presently disposed of by burning in natural draft teepee burners which emit smoke and odours. Municipal refuse is disposed of in an unacceptable landfill. A study has been carried out to determine the technical and economic feasibility of building a central facility to cleanly dispose of the wood and municipal waste in the Hearst area and by so doing to produce energy. The various available technologies for a central facility (e.g. gasification, steam and electricity generation) are evaluated and described. The study indicates that available waste can generate 250,000 lbs/hr of medium pressure steam which could supply steam heat to several nearby industries and municipal buildings (churches, schools, hospitals, arenas, etc.) enough electricity (12MW) to serve the town of Hearst and excess energy which could be utilized elsewhere, e.g., indoor swimming pools, greenhouses and/or sold to Ontario Hydro. A back pressure turbine with a conventional boiler is recommended. The economic analysis indicates that such a central facility could provide energy at a savings over the price currently being paid for power.

by

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WOOD WASTES TO ENERGY
A CENTRAL FACILITY FOR A TOWN IN NORTHERN ONTARIO

by

Dr. C. D. Burnham

D. B. Webber and D. K. Murdoch

This paper presents the results of a study carried out to examine the technical and economical feasibility of using wood and municipal wastes generated in the Hearst area as an energy source.

The study was unique in that a number of interested parties cooperated in its financing. These groups included the Town of Hearst, the Hearst Lumbermen's Association and the Ontario Ministries of Environment and Energy.

The idea of using the wastes as an energy source was conceived because the seven forest products facilities in the area are faced with ever-increasing energy costs, as well as possible restrictions on energy supply in the future. In addition they have the problem of disposing of their wood wastes in an environmentally acceptable fashion. The old-fashioned teepee burners are no longer considered acceptable. Also, the town of Hearst uses a landfill site for municipal refuse which is difficult to operate acceptably.

Hearst is a lumber town with a plywood and particleboard plant as well as two sawmills. There are three other sawmills within a 30-mile radius. An additional sawmill 90 miles away at Hornepayne was included in the study since trucks which presently carry wood chips from Hearst to Marathon via Hornepayne make the return trip empty.

INTRODUCTION (cont'd)

Hence it is conceivable that wood waste could be hauled fairly cheaply from Hornepayne to Hearst. Figure 1, shows a general map of the area and indicates the relative locations of the forest products facilities to the town of Hearst.

MATERIAL AND ENERGY BALANCE

Our first obvious task was an estimation of the balance between the waste quantities and Btu contents with the actual quantities of energy presently consumed within the Hearst area. Using figures on estimated production supplied by the mills to the Ministry of the Environment in Timmins, as well as practical experience of waste quantities from such operations, the following quantities of wood waste were estimated for the year 1976:

Source Breakdown		Oven Dried Tons/Year
Bark		72,000
Sawdust		50,000
Solid Wood		40,000
Miscellaneous		17,000
	Total	179,000

The solid wood fraction includes planer ends, trims, butt ends, limbs and branches reaching the mills. The miscellaneous category includes sweepings, shavings and sander dust.

MATERIAL AND ENERGY BALANCE (cont'd)

The estimated quantities of wood waste did not include wood chips, which are sold to the paper industry by the mills. Also, only 40% of the waste available from Newaygo Timber in Mead was included, as this mill consumes the remaining waste in its own energy generation facility. The Btu values used for the mixed wood quantitites was 8,000 Btu/lb. There is evidence in the literature that a combined Btu value for the bark, sawdust and solids is probably closer to 8,700 Btu/lb of bone dried solids. However, we chose to use a conservative figure for the potential Btu content of the waste. In addition, the moisture content of the wood waste was assumed to be 50%.

For municipal refuse, about 10 tons/day is picked up under contract to the town of Hearst. An additional estimated 10 tons/day is disposed of in the existing landfill site on contract from the larger industries and by residents living outside the town limits. An average of 5,000 Btu/lb of refuse with a moisture content of 40% was assumed.

Data on energy demand and consumption were obtained from those users in the Hearst area who could effectively be served by a central energy conversion plant. The two main forms of energy presently being used are natural gas and electricity. Natural gas is distributed directly to the users by Northern and Central Gas. The Hearst Public Utilities Commission (P.U.C.) distributes electricity supplied to it by Ontario Hydro to residential and industrial users within the boundaries of

Hearst. Ontario Hydro distributes directly to users outside the boundaries of Hearst.

From a close up of the town of Hearst (Figure 2) it can be seen that the institutional and municipal buildings are all reasonably close to each other and that the three forest products complexes - Levesque Plywood, United Saw Mill and Levesque Lumber Ltd. are also nearby.

The existing natural gas and fuel oil heating systems could be replaced by a number of alternatives such as steam, circulating hot water, electricity or synthetic gas. There is no really suitable replacement for the bulk of the electrical energy used other than electricity itself.

From the reported consumptions of natural gas and fuel oil of the industries and the institutional buildings, peak demand was projected and the total natural gas and the equivalent fuel oil consumption was estimated at approximately 614 million cu.ft. annually from 1973 to 1975. From the consumption figures and their monthly variations, the sum of hourly peak loads was calculated at 344 MCF/hr. Translating this into a natural gas equivalent steam requirement gives approximately 220,000lb. steam/hr allowing for the thermal efficiency of gas burning equipment. Thus the 220,000 lb/hr forms a basis for sizing the thermal energy conversion facility.

MATERIAL AND ENERGY BALANCE (cont'd)

The electricity demand level in 1976 was estimated to reach a peak of 10.66 MW and to rise by 1980 to 15.68 MW. Assuming that certain smoothing of peak demand can be implemented, or that peak power can be purchased for short periods from Hydro, the capacity of 12 MW was chosen for the proposed energy facility.

STUDY CRITERIA

Throughout the study a conservative approach was adopted, from the Btu values and moisture contents assumed for the wastes, to the estimates of capital and operating costs. Also, a number of criteria were established at the outset of the study. The technical criteria for selection of the system were that it should:

- use efficiently the waste wood and refuse quantities available,
- use established technology and readily available equipment,
- achieve a high load factor, representing maximum utilization of the installed equipment and therefore minimum capital cost,
- meet environmental regulations.

In addition it is conceivable that alternative uses for the wood residue may become viable in the future. Hence it was decided to use as a design criterion only up to 80% of the calculated available wood waste

STUDY CRITERIA (cont'd)

i.e., under 138,000 oven dried tons/yr.

The economic analysis was computed in 1976 dollars excluding inflation. Where prices were expected to increase more than could be expected by inflation, such as in the case of energy prices, this increase was taken into account. Based upon current rates and costs obtained from Ontario Hydro, Hearst P.U.C. the Hearst Lumbermen's Association and Northern and Central Gas, as well as escalation rates calculated from data supplied by Ontario Hydro, a set of prices was assumed for the study, as shown in Table 1. This is the cost of energy in 1976 dollars.

The actual energy prices in 1976 dollars are shown in Table 2. The distinction must be made between the cost of producing energy and the rates or price at which it is sold.

AVAILABLE ALTERNATIVE

Wood waste and municipal refuse can be utilized for energy recovery in a number of environmentally acceptable ways. For this study the following options which yield thermal and electrical energy were considered as alternatives to acceptable disposal with no energy generation:

AVAILABLE ALTERNATIVES (cont'd)

- low pressure steam generation
- medium pressure steam and electricity generation
- electricity generation
- synthetic gas production.

The energy demands met and the thermal efficiency of conversion are both functions of the system chosen. Hence the proportion of waste utilized to generate useful energy is dependent upon the option considered. Therefore, the percentage of waste used in each energy generation process will be indicated as each system is described.

OPTION 1 - LOW PRESSURE STEAM

In the low pressure steam generation option, waste would be trucked to a central facility, the wood waste hogged and municipal refuse shredded. The waste fuel would be fired in a conventional steam generator producing low pressure steam for distribution to industry and to the institutional buildings previously identified. Such a system could generate 250,000 lb/hr of saturated steam of 150 psig to replace the present natural gas demand and consumption of the identified users. A piping system for distribution of the steam and return of condensate, together with terminal equipment such as heat exchangers and steam injectors at the users' plants to convert existing heat loads to accept heat in the form of steam, would be integral parts of this installation.

In addition to the waste fuel firing equipment, the boiler would be equipped for natural gas firing to permit steam production during periods of non-availability of waste or breakdown of waste preparation equipment.

In the case of breakdown of the boiler or key piping system components, the steam users would resort to their existing heat energy sources which would be retained in working order to provide this standby function. A condenser would be provided to enable excess steam generated from wood waste to be disposed of. This would allow the plant to be used for incineration independently of the energy conversion requirements. Since the flow in the nearby river was not judged to be an adequate source of cooling water an air-cooled design was assumed for the condenser.

This option would use only 30% of the available waste, i.e. 55,000 oven dried tons/yr of wood waste to replace 700,000M cu ft/yr of natural gas.

OPTION 2 - MEDIUM PRESSURE STEAM AND ELECTRICITY GENERATION

In the medium pressure steam and electricity generation facility, waste would be trucked to the facility as described in the low pressure steam option. In this case the steam generated would produce medium pressure superheated steam which could be passed through a back pressure turbine exhausting to the steam distribution system. Such an installation would produce 275,000 lbs/hr of steam at 650 psig and $700^{o}F$ passing through a 12 MW turboalternator feeding electrical power into the Hearst P.U.C. system. Exhaust steam would be distributed to industry and institutions at 50 psig.

OPTION 2 - MEDIUM PRESSURE STEAM AND ELECTRICITY GENERATION (cont'd)

This system would use 138,000 oven-dried tons/yr or just under the 80% of the available waste to generate 60,000 MWH/yr steam equivalent to 700,000 MCF/yr of natural gas.

OPTION 3 - ELECTRICITY GENERATION

In the electricity generation option, a central plant consisting of a high pressure boiler supplying steam to a condensing turbine could be built. The system would be sized to generate 250,000 lbs/hr of steam of approximately 900 psig at 900°F to drive a 25MW turboalternator. The Hearst P.U.C. load would be met and a considerable excess of electrical power would be available for export to Ontario Hydro. No thermal energy would be produced. Thus the scheme would do little to reduce the natural gas demands of the town, and it would rely very heavily on revenue from sales of power to Ontario Hydro. This plant is sufficient to use all the available waste, assuming Ontario Hydro would buy all of the energy generated.

OPTION 4 - GASIFICATION

In the gasification option, waste would be brought to a central facility and fed to a gasification plant consisting of a number of modules operating in parallel. The low heating value gas (200 Btu/SCF) obtained would be scrubbed and a fraction of it used to incinerate the liquid products of reaction. The remainder would be available for distribution to the

industrial users of heat for fuelling internal combustion engine-driven electricity generators and for firing a boiler plant. Thus, the gasification process would generate electricity to feed the Hearst P.U.C. and would generate steam to serve the institutions. Use of the manufactured gas itself to replace natural gas is limited because of the low Btu content of the gas and because it would be difficult to distribute the relatively low pressure gas through an extensive piping distribution system. Thus, it was decided to use the gasification option to produce both steam and electricity, meeting the projected thermal energy demands and providing fuel for a 12MW generator station. This option would use 84% of the available wood waste.

ACCEPTABLE DISPOSAL, NO ENERGY GENERATION

For purposes of comparison, acceptable disposal with no energy generation was considered to be improved conical incinerators with supplemental fuel for the wood waste and a properly designed and operated sanitary landfill for the municipal refuse.

COST ESTIMATES

For the purposes of comparing the above alternatives, capital cost estimates of $\pm$ 20% were developed. Capital cost estimates included costs of land, mechanical equipment, piping, electric power and lighting, instrumentation and controls, civil works, installation and field erection, contingency and project management services.

COST ESTIMATES (cont'd)

In addition, operating cost estimates were developed including fixed annual costs, i.e. those costs that do not vary directly with the quantity of wood waste consumed and hence with the energy produced. These fixed annual costs included salary and wages of personnel, replacement parts, auxiliary gas or oil for burner start-up and for emergency steam production, electricity regularly used in the operation of the plant, standby fixed charges from Ontario Hydro, standby usage charges from Ontario Hydro and miscellaneous. Variable costs, i.e. the costs related directly to the quantity of residue used included transportation of wood residue, purchase of wood residue and disposal of ash.

The purchase of wood residue was a particularly touchy problem. For purposes of this analysis it was assumed that the waste was picked up at the mills free of charge. It is conceivable that the wood waste may someday have an alternative value. Alternative uses other than in the paper industry do exist, but they currently have relatively restricted markets although this situation may change. On the other hand, the disposal of wood waste without any energy generation would cost the mill operators something today, based on the costs of environmentally acceptable disposal. Hence one might consider that the wood residue has a negative value today, i.e., that one should pay for disposing of it. The cost of transportation of waste was established at $1.50/ODT within the town of Hearst and $3/ODT within the Hearst district, an average of 25 miles.

COST ESTIMATES (cont'd)

The cost of disposal of ash from the energy generation facility was calculated at $8.50/ton. This is assuming fairly stringent conditions for disposal of the ash, and includes both the transport and landfill cost. Transport cost was assumed at $1.50/ton assuming that suitable land could be found for disposal within the boundaries of Hearst. The landfill costs were assumed to be $7/ton. It is likely that this cost of disposal could be reduced to within the order of $3/ton for the landfill portion.

Costs of acceptable disposal of both wood waste and municipal refuse without energy generation were also estimated. For municipal refuse, disposal costs were assumed to be $7/ton by acceptable methods. For acceptable wood waste disposal, a capital cost of $150,000 was used for an acceptable teepee burner with supplementary fuel. The amortized annual cost was thus $20,000/yr. Annual operating costs were estimated at about $44,000/yr. yielding a disposal cost of $1/ton to $1.50/ton depending upon whether the burner was operated on a continuous basis or not.

ECONOMIC ANALYSIS

To establish the viability of the proposed plant, the criterion of internal rate of return of the project was used to compare the various options. The internal rate of return is the rate of interest, or discount rate, at which the present value of the future annual net revenues is exactly equal to the capital cost of the project. This must be between 4 to 5%, excluding inflation, to be acceptable. Including inflation, the rate would have to be 9.75 to 10.5% to be acceptable.

ECONOMIC ANALYSIS (cont'd)

The life of the project for economic purposes was assumed to be 20 years, i.e., a 20-year amortization was used. The rates of return obtained for the various options are shown in Table 3.

High and low costs in the table refer to high and low estimates of operating costs. Certain assumptions were made with regard to operating costs. If certain savings could be made in the operating costs, the rate of return would of course be improved.

As can be seen,options 2 and 3, medium pressure steam plus electricity generation and electricity generation offer the two best rates of return.

Table 4 indicates the degree to which each of the options respects criteria other than economic. Only option 2, is considered acceptable for all of the criteria, i.e., using less than 80% of the wood residue available, using proven technology, environmental acceptability and efficient energy conversion. It is not considered efficient energy conversion to produce electricity solely for sale to Ontario Hydro. We considered it preferable for the town of Hearst to be self-sufficient in its energy needs, exporting only electricity not useable by Hearst to Ontario Hydro.

DETAILED ANALYSIS OF SELECTED OPTION

Having selected steam and electricity as the most viable option from a technical and economic point of view, this alternative was developed and examined in greater detail.

DETAILED ANALYSIS OF SELECTED OPTION (cont'd)

A potential site was selected, flow diagrams, a site plan, a general arrangement and a perspective of the energy conversion facility were prepared. These drawings are, of course, only conceptual at this stage. Should the project proceed, detailed engineering would have to be carried out.

Based on the conceptual design, the original estimates were refined and a more detailed economic analysis was carried out.

SITE SELECTION

Within the constraints of the local geography and proposed technology, the criteria for site selection included:

- proximity to centroid of thermal load to minimize piping runs
- good road access
- adequate area for wood waste storage
- level ground
- conformity with Hearst Town Plan
- availability of property.

Several potential sites were examined and a tentative location (confidential) was chosen.

CAPITAL COSTS

The capital cost of the project was estimated to be \$15,200,000 $\pm$ 10 to 15%.

LIFE OF THE PROJECT

The technical life of the plant in terms of desirability of equipment was judged to be in excess of 30 years. Since the economic life could be shortened by the development of more lucrative uses for wood waste, a project life of 20 years was used for the economic analysis.

DETAILED ECONOMIC ANALYSIS

A more detailed economic analysis of the steam and electricity option was carried out to determine the anticipated rate of return under various scenarios of operating costs, quantities of electricity sold, disposal charges, and the effects of inflation.

The effects of different energy price levels, as well as the levying of a disposal charge, and quantities of energy sold on the rate of return (excluding inflation) and the payback period are indicated in Table 5. The results indicate a reasonable likelihood of attaining a rate of return in the order of 5 to 8%.

With inflation taken into account, our analysis indicated that the internal rate of return increased to 9½% with no disposal charge and to 10½% when a disposal charge is included for the wastes. Hence the viability of the project improves when inflation is considered.

OWNERSHIP

Four ownership possibilities were evaluated against the following criteria:

- compliance with public utility regulations
- qualification for tax exempt status
- guarantee of supply of wood wastes
- protection of public interest.

The results, as shown in Table 6, indicate that the most attractive option is that of ownership by the Hearst P.U.C. with possible minority holdings by the principal beneficiaries of the project, namely the industries. This option would meet public utility regulations, guarantee the public interest and tax exempt status. However, it would require a guarantee of waste supply by the participating mills.

FINANCING

A number of financing possibilities were investigated. It was concluded that grants and guaranteed loans were required to allow the energy system to operate on a sound financial footing.

The proposed split in funding is as follows:

Town of Hearst and Hearst Lumbermen's Assoc. industries	20 - 30%
Grants	20 - 30%
Guaranteed Loans	40 - 60%

The actual proportions will depend upon a detailed study of available grants, the approval of these grants, and the results of negotiations between the interested parties.

TO SUM UP : the study has indicated that the rate of return for the project would be just adequate to justify support by the Provincial Government. However, as we have indicated all along in the study it is anticipated that a number of improvements could be made which would improve the rate of return even further.

PLAN OF ACTION

This is just the beginning. To proceed any further with this project would require commitments from the waste suppliers and Ontario Hydro, among others.

Table 7 lists the actions required for implementation of the project.

ACKNOWLEDGEMENTS

We would like to thank a number of individuals and organizations for their cooperation throughout the study, in particular the members of the Hearst Lumbermen's Association and the Town of Hearst, the Ontario Ministries of Energy, Environment and Natural Resources, Ontario Hydro and Northern and Central Gas.

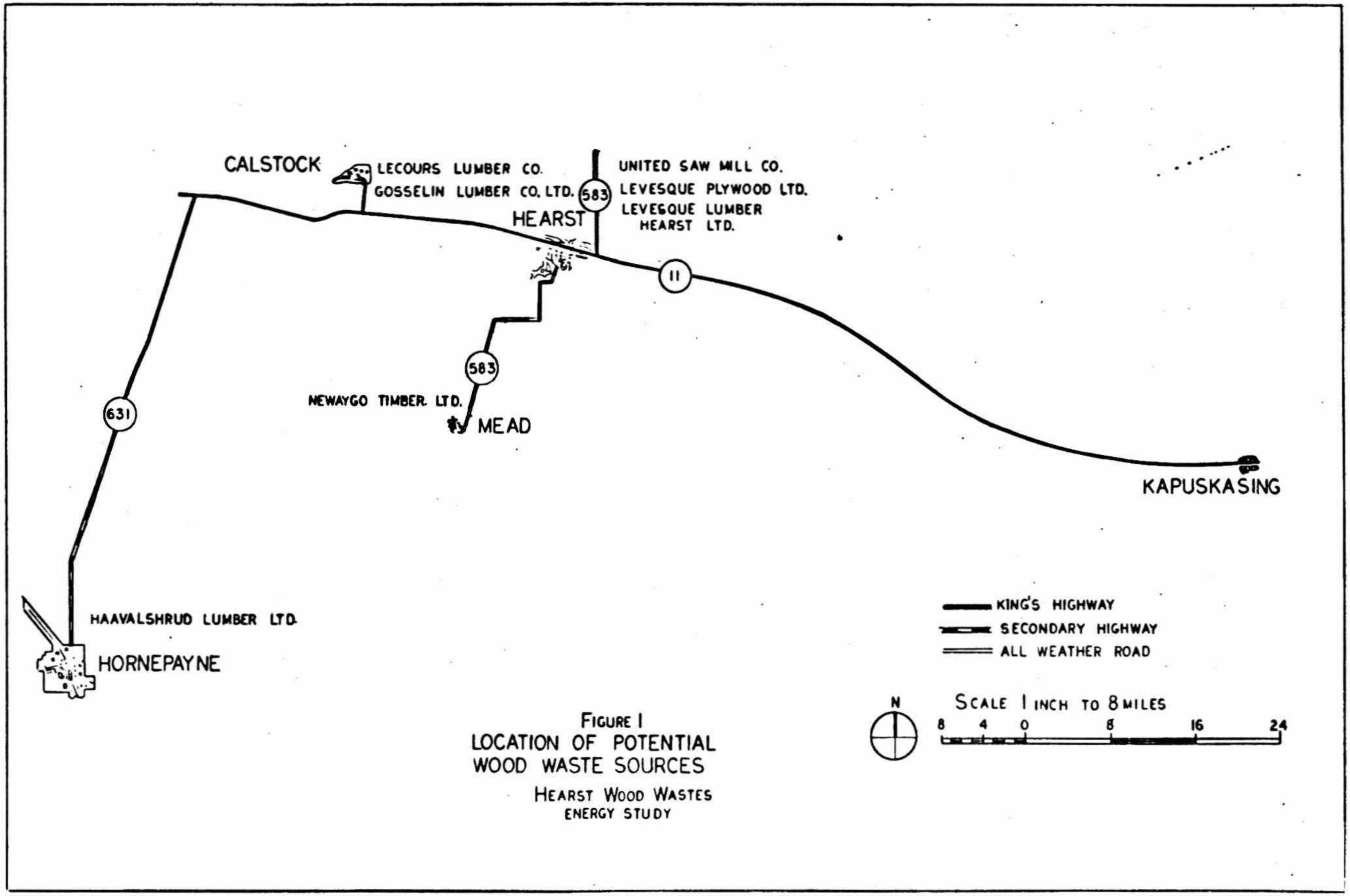

FIGURE I
LOCATION OF POTENTIAL
WOOD WASTE SOURCES
HEARST WOOD WASTES
ENERGY STUDY

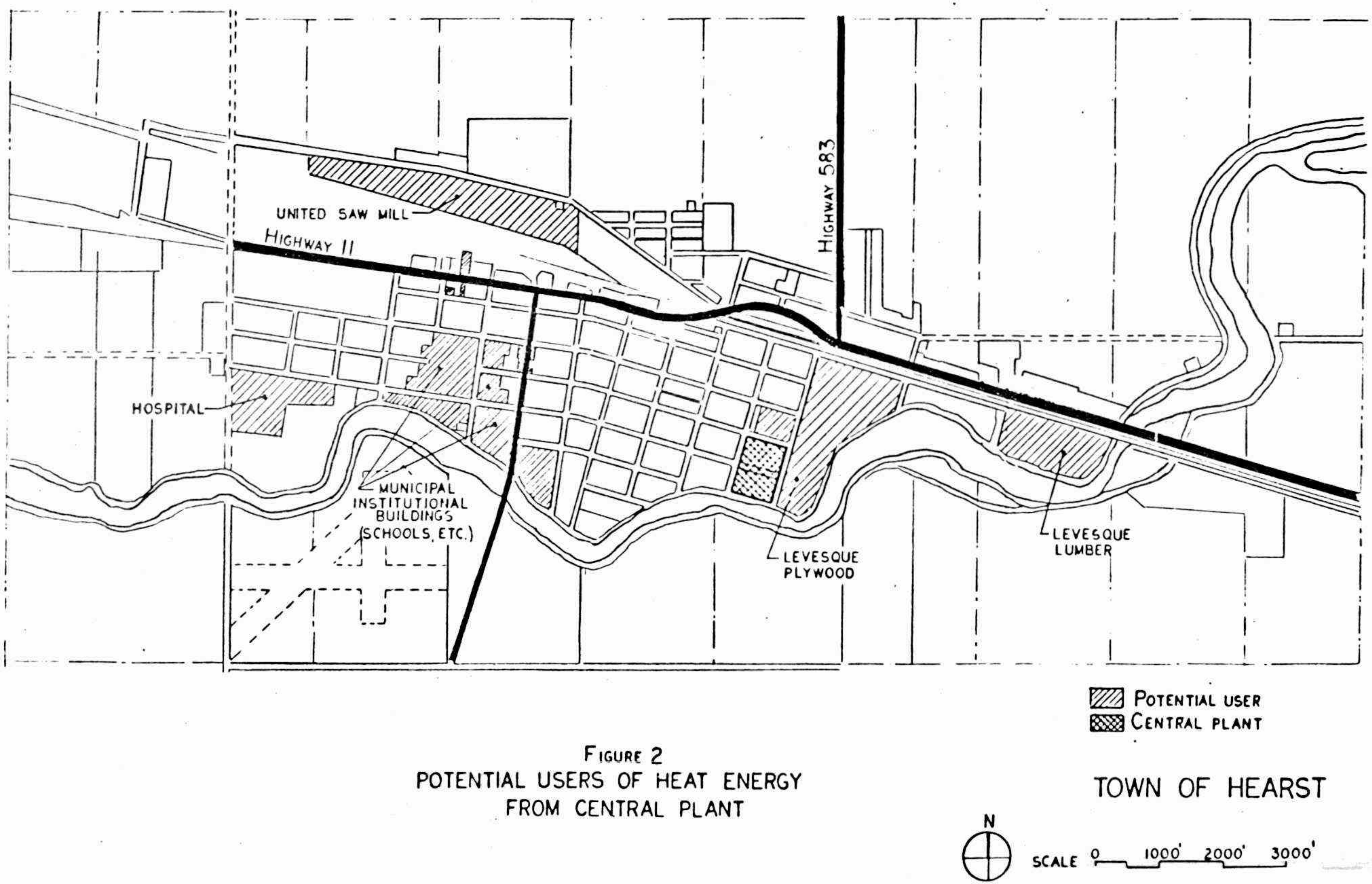

FIGURE 2
POTENTIAL USERS OF HEAT ENERGY
FROM CENTRAL PLANT

TABLE 1

Cost of Energy
(1976 dollars)

Source		Year 1976	Year 1980
Electrical Generation (Province Wide)		12.0 mils.	15.0 mils.
Natural Gas	(wholesale)	\$1.20/MCF	\$1.92/MCF
	(cost in Hearst)	\$1.50/MCF	\$2.25/MCF
Wholesale Electricity Purchase by Hearst		15.0 mils.	19.5 mils.

TABLE 2

Energy Prices 1980
(1976 dollars)

Energy		Price High	Price Low
Natural Gas	(wholesale)	$1.80/MCF	$1.45/MCF
	(cost in Hearst)	$2.00/MCF	$1.80/MCF
Electricity:	Generation Cost	15.0 mils.	12.0 mils.
P.U.C. Wholesale Rate		19.5 mils.	17.5 mils.

TABLE 3

SYSTEM EVALUATION
RATES OF RETURN

SYSTEM	RATES OF RETURN - %							
	65,000 MWH 15 mils				85,000 MWH 15 mils			
REVENUE / COSTS (1)	HIGH		LOW		HIGH		LOW	
DISP. CHARGE (2)	No	Yes	No	Yes	No	Yes	No	Yes
1. STEAM	-1	0	2	-	-	-	-	-
2. STEAM + ELECTRICITY	2	4	5	7	3	5	6	8 *
3. ELECTRICITY	-	-	-	-	5	6	7	8 *
4. GAS + STEAM + ELECTRICITY	-3	-1	1	2	0	1	3	4

Notes: (1) Costs HIGH and LOW refer to variations in operating costs.

(2) No and yes indicates rates with and without a disposal charge levied for the waste.

TABLE 4

GENERAL
SYSTEM EVALUATION

OPTION / CRITERIA	1. STEAM	2. STEAM + ELECTRICITY	3. ELECTRICITY	4. GASIFICATION
WOOD RESIDUE < 80% USED	●	●	–	–
PROVEN TECHNOLOGY	●	●	●	–
ENVIRONMENTAL ACCEPTABILITY	●	●	●	●
EFFICIENT ENERGY CONVERSION	◐	●	○	○

● Good

◐ Moderate

○ Poor

— Negative

TABLE 5

Steam and Electricity Option
Detailed Analysis of Rate of Return

ENERGY SOLD	RATE OF RETURN					PAYBACK PERIOD (years)	
	Revenue	Medium					
	Costs	High		Low			
	Charge	No	Yes	No	Yes	Max.	Min.
Steam (Gas Equiv.: 700,000 MCF)							
Plus							
65,000 MWH		3.5	5.0	6.5	8.0	14	9
75,000 MWH		4.0	6.0	7.0	9.0	13	8
85,000 MWH		5.0	7.5	8.0	10.0	12	8
65,000 MWH *		5.5	7.5	8.5	10.0	--	-

Revenue: Medium, Gas/Steam $ 1.80/MCF
Electricity $ 17.55 mils.

Costs: High: $ 1,036,000./yr
Low: $ 660,000./yr

Yes = Disposal Charge of:
Municipal: $ 20,000.

Industries: $ 1.50/ton

No = No Disposal Charge

* Revenue at: Gas/Steam: $ 2.00/MCF
Electricity: 19.5 mils.

TABLE 6

OWNERSHIP OPTIONS AND CRITERIA

	HEARST PUC 90%	HLA	THIRD PARTY (PUBLIC)	PUC + HLA
Public Util. Regulations	●	-	●	◑
Public Interest	●	-	◑	●
Tax Exemption	●	-	●	-
Waste Supply	○	●	○	●

● Positive
○ Possible
◑ Dependent upon details of scheme
\- Negative

TABLE 7

RECOMMENDED PLAN OF ACTION

1. Obtain commitments from participants, including waste suppliers, Ontario Hydro, Hearst P.U.C., energy users and the Hearst Lumbermen's Association.

2. Establish a steering committee authorized to make and execute decisions.

3. Negotiate funding with appropriate government agencies.

4. Establish and incorporate organization.

5. Confirm design criteria for the facility.

6. Sign agreements with the participants.

7. Carry out additional technical and economic investigations required (e.g. soil conditions etc.).

8. Confirm site location and obtain site.

9. Place contracts for engineering and construction of the facilities (including steam distribution system and energy conversion facilities at user locations).

10. Takeover constructed facility.

11. Operate and manage facility.

WASTEWATER TREATMENT AND OIL RECLAMATION

AT GENERAL MOTORS, ST. CATHARINES

In April 1974, the Liquid Waste Treatment Plant located at the Axle Plant in St. Catharines, Ontario, became operational. All industrial process waste from the Axle and Engine Plants is treated at this three million dollar reclamation facility. Over 270,000 gal. of liquid waste which consists chiefly of various used oils, greases, washing chemicals and process water are treated per day. The functions of the treatment plant are three-fold: (1) to separate the petroleum products from the water phase via the 'acid-alum process', (2) to remove pollutants from the water in compliance with Regional and Provincial laws & (3) to remove contaminants present in the separated oil, reclaim and recycle these oils back to the manufacturing plants. The chemically treated water is discharged to city sewers; whereas, the reprocessed oil is blended with various additives making it suitable for in-plant use. At present, over 225,000 gal. of soluble oil concentrate and 100,000 gal. of cutting oil are annually produced at this reclamation plant at economical prices. Experiments currently in progress indicate the feasibility of formulating hydraulic oil from G.M. reclaimed oil.

by

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Mr. Johnson graduated from the University of Guelph in 1969 with an Honours B.Sc. degree in Marine Biology and in 1972 with a M.Sc. in Aquatic Biology. During the summer months of his university career he conducted biological surveys while employed by the Ontario Water Resources Commission. Upon graduation he was hired by General Motors of Canada and is presently the Chemist at the company's Liquid Waste Treatment Plant in St. Catharines. In this capacity he is responsible for the various chemical processes and development of additional reclaimed petroleum products at this treatment facility.

WASTE WATER TREATMENT AND OIL RECLAMATION AT GENERAL MOTORS OF CANADA LIMITED ST. CATHARINES AXLE PLANT

by

Ross E. Johnson Jr.

In April 1974, the Industrial Waste Liquid Treatment Plant located at the Axle Plant in St. Catharines, Ontario, became operational. Prior to the construction of this treatment facility, all the liquid waste from the Axle Plant was separated into one of three different sewer systems:

1. Sanitary Sewers - waste is discharged to the Regional Niagara Treatment Plant.
2. Storm and Cooling Sewers - waste is transferred to a containment pond at the Axle Plant prior to discharge into the Twelve Mile Creek.
3. Process Sewers - waste is pumped into the Waste Liquid Treatment Plant before being discharged into the City sewer system.

Prior to April 1974, heavily contaminated process waste was either transported to oil reclaimers or to approved disposal sites. However, this resulted in high haulage costs and the loss of a much needed oil source. These factors, in addition to our concern for protecting the environment, precipitated the design and construction of a water treatment and oil recovery plant at St. Catharines.

All industrial process waste from both the Engine and Axle Manufacturing Plants is treated at this three million dollar reclamation facility. Over 270,000 gallons of liquid waste are processed per day. This waste consists chiefly of various used oils (example - water soluble, hydraulic, cutting and quench oils), greases, washing chemicals and process water.

The functions of the treatment plant are three-fold:

1. Separate the petroleum products from the water phase via the "acid-alum process".
2. Remove pollutants from the water in compliance with Regional and Provincial laws.
3. Remove contaminants present in the separated oil, reclaim and recycle these oils back to the Manufacturing Plants.

The process waste collected from the Engine Plant is transported approximately five miles to the treatment plant via 5,000 gallon tank trucks. An overhead pipe trestle conducts liquid waste in addition to steam, condensate and compressed air from the Axle Plant to the reclamation centre.

The oily waste from both plants passes through two circular rotary sieves which contain a heavy gauge wire screen to separate large sized particles. After these solids are removed, the waste is pumped into one of three large 450,000 gallon holding tanks. While one tank is filling, the contents of the second tank are treated; whereas, the third storage tank is on standby.

Upon filling a holding tank, the waste is stored under quiscent conditions for at least one to two days. This permits the "free" or unemulsified oil to rise to the surface and be skimmed off into two oil storage tanks. This material is called "skim oil". After skimming, the remaining waste may be mixed to prevent stratification by introducing compressed air into the bottom of the storage tank.

The heavier emulsified oil, located below the skim oil, is pumped at a rate of 400 g.p.m. into alum tank #1. This tank is a 4,000 gallon fibreglas vessel. The pH of the alkaline waste is

lowered to 4.5 in this tank with the addition of sulphuric acid and liquid alum. These two chemicals split the emulsion enabling the oil to combine with the alum to produce a floc. Since floc formation and its subsequent separation from the water phase is enhanced at a higher pH, the oily waste flows by gravity into alum tank #2 where caustic soda (sodium hydroxide) is added to raise the pH to 6.0.

Because floc consists chiefly of alum, oil and suspended solids, the function of the next step of the process is to remove these floc particles from the water. This separation is accomplished in two floatation tanks with the aid of dissolved air and a polyelectrolyte. When air under pressure is released into the bottom of each floatation unit, tiny air bubbles are formed. As these bubbles unite with the floc particles, their buoyancy is increased. This causes the floc to float to the surface and separate from the water phase at a rate much faster than normal. Addition of an anionic polyelectrolyte causes the floc particles to aggregate together to form long chain-like structures which facilitates floc removal. The floc layer, which is also called "scum oil", is removed into two storage tanks from the floatation units by means of an electrically-timed skimming mechanism.

The fluid below the scum oil in the floatation tanks is clean water which flows by gravity into a 420,000 gallon clarifier. Materials having a specific gravity less than water will float to the surface and be removed by a skimmer; whereas heavier than water particles will sink to the bottom. The clean water discharged from the clarifier flows into the City sewers and receives additional

treatment at the Port Dalhousie Pollution Control Plant.

At present it is uneconomical to recycle the treated water from the clarifier back to the Axle Plant. However, increasing water costs will make water reclamation and re-use feasible in the future.

The composition of the process waste varies continuously depending upon the type of material discharged from the two Manufacturing Plants. As a result, the oily waste being treated is analyzed several times throughout the day using the "jar test" procedure. Results of these tests allows the operator to select the optimum concentration of the various water treatment chemicals. As an example, if the waste contains a higher than normal percentage of emulsified oil, more alum and polyelectrolyte may be required.

To ensure that the effluent from the clarifier is clean and conforms to the By-law, the water is monitored for pH, oil content and suspended solids (Table 1). To demonstrate the high quality of water originating from this plant, a 30 gallon aquarium was filled with water from the clarifier. This tank was stocked with 15 different tropical fresh water fish species. Normal behaviour and mortality have been observed among the fish population during the 10 months of its existence.

The skim and/or scum oil are pumped into one of three 4,000 gallon oil reactors. Concentrated sulphuric acid (1-2% by volume of tank contents) and a proprietary mixture (1-2% by volume of tank contents) containing polymers and surfactents are

mixed with the oil. The resultant mixture is heated by steam coils to 180-200°F and allowed to settle undisturbed with the heat off for 8-12 hours. During the settling period, the fluid separates into three phases (Figure 1):

Semi-processed oil (upper layer) - pumped into the oil polishing reactor for additional treatment.

Water and alum (middle layer) - discharged to the 450,000 gallon holding tanks as reclaimed alum.

Sludge (bottom layer) - transferred to a sludge storage tank. (All sludge deposits are transported via tank trucks to disposal sites approved by the Ontario Ministry of the Environment.)

The semi-processed oil from the three oil reactors is pumped into one 4,000 gallon polishing tank. Another proprietary material (1/4-1/2% by volume of tank contents) acting as a "chemical broom" separates the suspended contaminants present in the oil. Sufficient sodium hydroxide is mixed with the oil to neutralize the strong acid constituents such as sulphuric acid. The contents of the reactor are recirculated and heated to 180-200°F, within a 3-4 hour interval. After mixing, the heat is turned off and the mixture settles for 12-18 hours. Again, three distinct layers emerge in the tank. They consist of polished oil (upper layer), water and alum (middle layer), and sludge (lower layer). Since most of the contaminants are removed in the oil reactors, the polished oil layer accounts for approximately 90% by volume of the tank contents; the remaining 10% includes water and sediment (Figure 2). Polished oil typically

contains less than 0.05% water and 0.1% dirt.

Just as the water treatment process varies with the changing composition of the waste, in like manner each 4,000 gallon batch of oil must be "jar tested" individually to determine the correct chemical procedure. Occasionally caustic soda may be used in place of sulphuric acid in the oil reactors in order to maximize the oil yield. If this is done, acid is employed in the polishing tank to neutralize the alkaline oil.

The neutralized oil is further purified from residual sediment deposits as it passes through a self-cleaning centrifuge. By centrifugal action, a layer of sludge accumulates along the walls of the bowl. A plow removes this cake layer from the walls and discharges the solids through a chute located at the bottom of the centrifuge to a conveyor.

Centrifuged oil, now called base oil, is transferred to one of two 10,000 gallon oil separators. In the separators, the oil is retained for approximately one week and kept at a constant temperature of 120°F. Trace concentrations of water and dirt contaminants remaining in the oil sink by gravity to the bottom of these funnel-shaped separators and are drained to the sludge tank. After a week, the base oil is discharged to one of two 10,000 gallon unfiltered oil tanks. Oil is retained in these storage tanks until a soluble or cutting oil product is required.

Upon request for a lubricant from the Manufacturing Plants, the operator pumps the base oil through a filter. The filter housing contains replaceable fibre cartridges which range

in size from 5-50 microns. Cartridge selection is based upon the degree of cleanliness required in the oil. After filtration, the base oil is pumped directly into a 10,000 gallon filtered oil storage tank and then into one of two 4,000 gallon blend tanks.

One blend tank is used exclusively for formulating soluble oil while only cutting oil is blended in the second tank. A 5% sulfo-chlorinated mineral oil concentrate is mixed with 95% base oil to produce a cutting oil containing anti-weld and anti-wear characteristics. Over 100,000 gallons of reclaimed cutting oil are used annually in the automatic screw machines at the Axle Plant. Soluble oil concentrate consisting of a 20% emulsifier package and 80% base oil is used extensively throughout the Engine and Axle Plants. Its widespread usage is indicative of the product's excellent emulsion, cutting and cooling properties. At present, 225,000 gallons of reclaimed soluble oil concentrate are used in machines ranging in size from small 25 gallon coolant tanks to large 25,000 gallon central coolant systems. Experiments currently in progress indicate the feasibility of formulating hydraulic oil from G.M. reclaimed base oil.

Typical specifications for filtered base oil are shown in Table 2. It is readily apparent that the oil is low in contaminants, relatively uniform in composition and high in quality. Small quantities of sulphur, chlorine and phosphorus are beneficial in the oil since they serve as extreme pressure additives which facilitates cutting.

The laboratory in the treatment plant contains the main

control console, a computer and suitable bench space for the operators to conduct various chemical-physical tests on oil and water samples. The main console consists of an array of gauges, charts, flow diagrams, pumps and valve controls. This control panel allows the operators to regulate from the lab most of the mechanical operations occurring within the treatment building. Owing to the high degree of automation, three men operate the entire plant during the day shift and two employees work the afternoon shift. One operator is responsible for water treatment, the second for oil reclamation, while the third is engaged in maintenance and trouble-shooting. Much of the data monitored on the control console is stored in a computer. This recording device provides useful information on various chemical and physical parameters such as chemical usage, mechanical failures, flow rates, temperatures, pH's, etc.

To ensure high standards in the finished oil products, several quality control checks are performed in the lab prior to shipment to the Manufacturing Plants. As an example, soluble oil is tested for emulsion stability, pH, water and dirt content and bacterial contamination. If for some reason a batch of soluble oil does not meet our specifications, the product is modified in the blend tank until good quality is assured.

Significant cost savings result when we use our reclaimed oil products in contrast to purchasing new materials from a vendor. Our reclaimed cutting and

soluble oils are competitive to new oils both in cost and quality.

Not only is it advantageous for us to reclaim oil but it is also profitable to collect "used" fire-resistant fluids and chlorinated degreasing solvents and send these products to outside vendors for reclamation. As a case in point, substantial savings are realized by using reclaimed phosphate ester fire-resistant fluid which has been reconditioned to meet stringent specifications.

As global oil reserves are depleted, as the cost of new oil products continues to increase on world markets, and as laws governing the quality of effluents become more stringent, the necessity of recycling exhaustible petroleum products assumes paramount importance. General Motors is concerned about environmental problems and the conservation of limited resources. Construction of this water treatment and oil reclamation centre represents a positive step forward towards a cleaner, safer world for tomorrow.

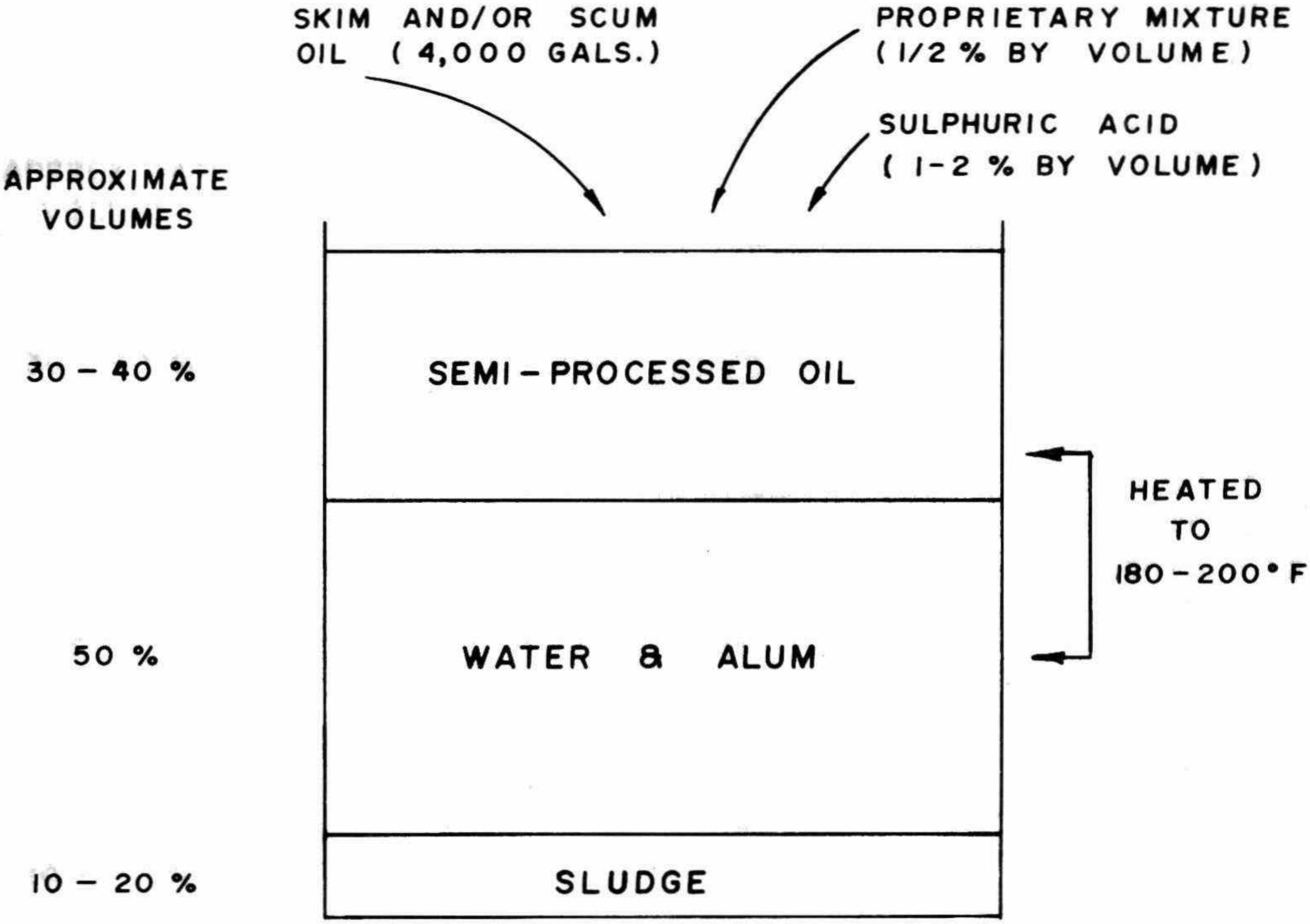
TABLE 1 WATER CHARACTERISTICS

PARAMETER	UNTREATED WASTE WATER INFLUENT	TREATED WASTE WATER EFFLUENT	EFFLUENT LEGAL LIMITS (Regional By-Law)
Oil	3,000-7,000 ppm	5- 12 ppm	less than 15 ppm
Suspended Solids	500-1,000 ppm	150-300 ppm	less than 350 ppm
pH	7.5-10.0	6.3-6.8	5.5-9.5

TABLE 2 FILTERED BASE OIL CHARACTERISTICS

PARAMETER	RANGE
Viscosity @ 100°F	125-135 SUS
@ 210°F	40- 45 SUS
Viscosity Index	87-100
Flash Point (COC)	330-360°F
Water	less than 0.02%
Sediment	less than 0.03%
Sulphur (Total)	0.4-0.6%
Chlorine	0.1-0.15%
Phosphorus	0.1-0.2%

TREATMENT PROCESS AT OIL REACTORS



CONTENTS ALLOWED TO SETTLE UNDISTURBED FOR 8 TO 12 HOURS

FIGURE 1

TREATMENT PROCESS AT POLISHING TANK

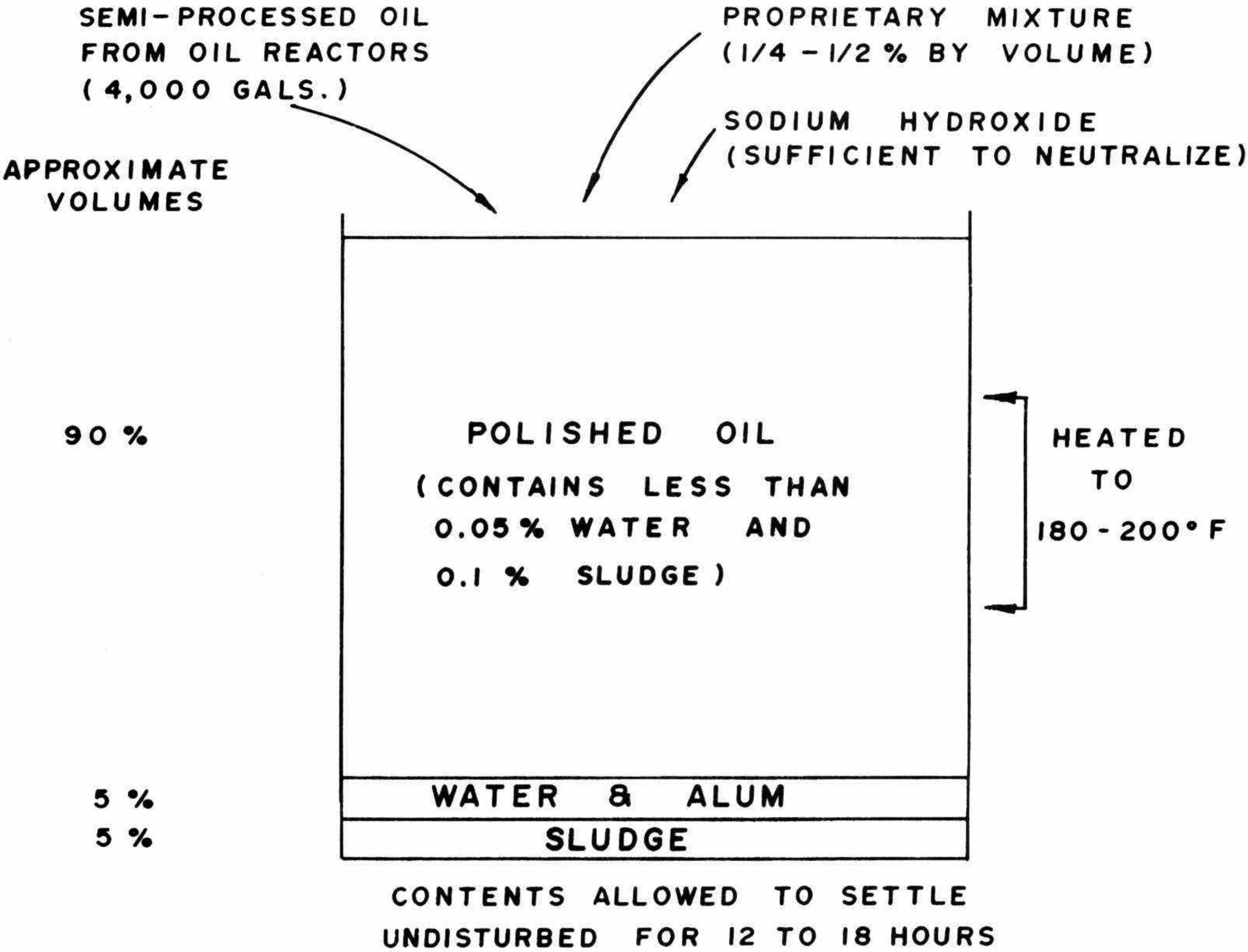


FIGURE 2

CRYOGENIC SHREDDING AND RESOURCE RECOVERY

The science of Cryogenics will be 100 years old come December 25, 1977. The use of Cryogenics for the recycling of certain solid waste materials appears to be a relatively new solution to an age old problem. It has been estimated that 75 per cent of our natural resources that are now being thrown away in the nations' waste system could be reclaimed and recycled by the end of this decade. Most commodities are made up of multi-materials, in that they are either laminated or mixed. Cryogenics can play an important part in the separation of many kinds of materials. The automobile and truck tire, generator, alternator and starter motor are excellent examples of commodities that can be effectively, efficiently and economically processed using the Cryogenic technique.

Cryogenically processed materials are usually in such form when they leave the mill that they can be easily separated. For example, by reducing the temperature of an automobile alternator to $-130^{\circ}F$ ($-90^{\circ}C$) and subjecting it to the impacts of the hammers in a mill, the steel will shatter into small fragments, leaving the copper in coil form. A magnetic separator will lift the steel away from the copper, and air flotation will remove any fibres, leaving a number one grade of copper with 100 per cent recovery.

by

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Professor Braton, born in Barnesville, Minnesota, received his B.S. degree from State College, Minnesota, and his M. S. from the University of Minnesota. After service in the U.S. Army, 1941-46, he was an instructor of Industrial Arts, became associated with the University of Wisconsin in 1955 and was appointed Professor in Mechanical Engineering in 1970. He has conducted welding institutes, given lectures throughout Japan and India, and has served as a consultant for commissions, associations and foundations as well as numerous industries. He is presently actively involved in the research of cryogenic recycling of solid wastes, disseminating information to many countries throughout the world and has authored an presented many papers on the subject.

CRYOGENIC SHREDDING AND RESOURCE RECOVERY

by

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The term recycling refers to the transformation of waste materials into useable products. Transforming waste materials, however, is not often accomplished in one simple step. It may involve several steps including separation, transportation, cleaning, and reforming the materials to be recycled.

The term "cryogenic recycling" refers to a recycling technique which utilizes the brittle behavior of some materials at reduced temperatures to aid in the transformation of waste materials. It is called "cryogenic" recycling because many materials need to be cooled far below ambient conditions before they will become brittle. How low a temperature is needed to embrittle materials, if at all possible, depends upon such things as crystal structure, molecular weight, previous coldworking, crystal grain size, composition and other physical characteristics which will be discussed later.

Because not all materials embrittle at low temperatures there has developed a need for a classification of materials which can be recycled cryogenically, a classification of materials which are brittle at low temperatures. A few examples will be cited to illustrate the mechanical behavior a material must show before it can be classified as cryogenically recyclable.

At room temperature, natural rubber (polyisoprene) is ductile. However, at some lower temperature, natural rubber becomes brittle. Thus, natural rubber is said to go through a ductile-to-brittle transition and can be classified as cryogenically recyclable. Copper, on the other hand, which is also ductile at room temperatuer will not go through a ductile-to-brittle transition at low temperatures. Thus, copper is not cryogenically recyclable.

Many separation processes now in use depend on the brittle behavior of some materials and the ductile behavior of others.

For a long time the recycling of copper from plastic coated copper wire consisted of burning the plastic to recover the copper. As a result of burning, the copper became an oxidized lower grade of scrap. The burning of the plastic such as polyvinyl chloride resulted also in the emission of noxious vapors such as chlorine. This burning is now prohibited by law unless a scrubber is used along with the incinerator to remove the noxious substances [1]*. The Federal Clean Air Act of 1963 and its

*Bracketed numbers refer to references in the bibliography.

Amendments of 1970 (Public Law 91-604) together with the Wisconsin Administrative Code Chapter NR 154, Air Pollution Control, prohibits the open burnings of rubbers and petrochemical products. Scrubbers placed in smoke stocks wash the products of combustion to remove the noxious vapors before they can be released into the atmosphere.

Now plastic coated copper wires can be recycled cryogenically. The cryogenic processing of plastic coated cables involves embrittling the plastic coating by reducing its temperature and impacting the cable. Upon impacting the brittle plastic will shatter into small pieces while the ductile copper wire remains whole. Finally, the plastic and wire are separated by conventional techniques.

The cryogenic process not only yields a high grade of scrap but also eliminates the noxious vapors and the need for costly scrubbers. The cryogenic process also produces a plastic which can be reused.

It should be noted that due to the definition of cryogenically recyclable materials, materials which are brittle at low temperatures, that the copper is not a cryogenically recyclable material but the plastic which became brittle is. However, the whole cable can be recycled using a cryogenic process.

MATERIALS CLASSIFICATION

Materials are classified into three groups, namely metals, ceramics and polymers. Each of these groups can be identified by subdivision (Fig. 6).

In order to be classified as cryogenically recyclable a material must be able to be fractured in a brittle manner. "Brittle" meaning fracturing with no apparent plastic deformation.

Some materials will be brittle at room temperatures. Others have to be cooled far below ambient temperatures before they can br fractured in a brittle manner. Still others are ductile at both room and reduced temperatures.

To investigate brittle fracture and the factors affecting brittle fracture it is convenient to study the yield stress and fracture stress behavior of materials. Figure (1-a) is a schematic showing the yield and fracture stress behavior of a material which would fracture in a ductile manner, yielding before fracture at both high and low temperatures. This type of material would not be classified as cryogenically recyclable.

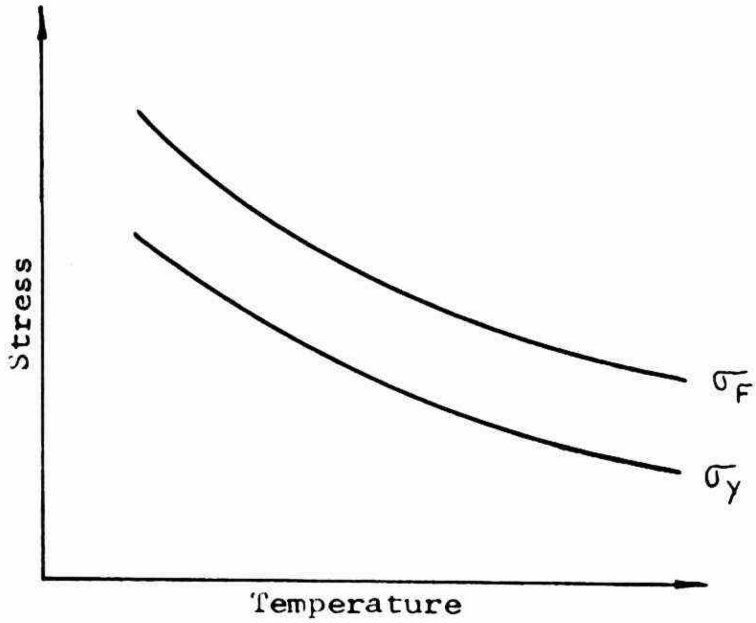


Figure 1-a

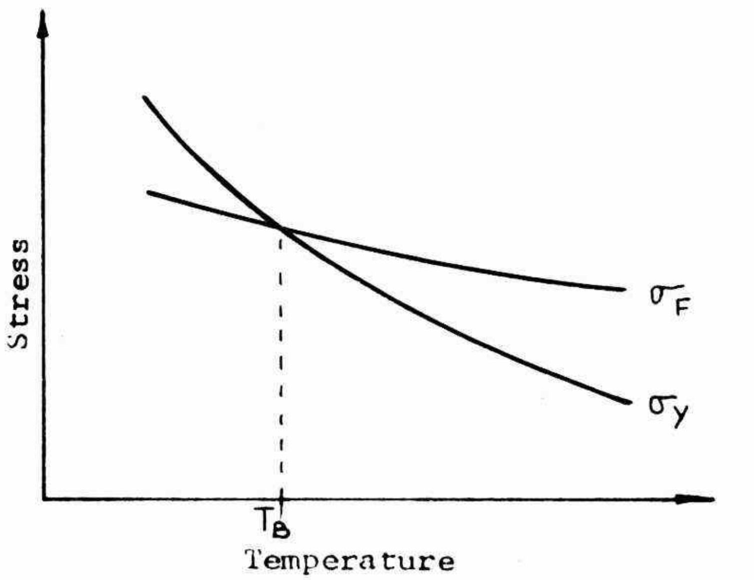


Figure 1-b

Figure 1. Schematic showing the yield stress and fracture stress of: (a) a ductile material, (b) a material which goes through a ductile-to-brittle transition.

Figure (1-b) is a schematic showing the yield and fracture stress behavior of a material which is ductile at room temperature but brittle at some lower temperature. This type of material is said to go through a ductile-to-brittle transition at T_B, the Brittle Temperature. Below T_B the material would fracture in a brittle manner, fracturing before yielding. Thus, this type of material could be classified as cryogenically recyclable.

Materials which fracture in a brittle manner at room temperature have the room temperature lower than T_B and can also be classified as cryogenically recyclable.

Temperature isn't the only factor which affects the yield and fracture behavior of materials. Increasing the rate of loading has the same effect on the yield and fracture stresses as lowering the temperature. Figure (2) demonstrates the effect of increasing the rate of loading on the ductile-to-brittle transition temperature.

The increase in T_B due to increasing the rate of loading is the cause of much confusion when trying to quote a particular value of T_B. A value for T_B is only valid for a particular type of test and a particular rate of loading. Unfortunately, very few researchers provide this type of information when publishing values of T_B. This makes comparing different brittle point data difficult. Figure (3) shows how the rate of loading affects T_B for Tungsten, Zinc, polymethylmetharylate (PMMA) and polyvinyl chloride (PVC).

Many of the cryogenic recycling processes depend on the selective embrittlement of materials. For instance the cryogenic recycling of plastic-coated copper cables relies on the plastic embrittling and the copper wire remaining ductile. Figure (4a) depicts the yield and fracture behaviors of ductile copper wire and a plastic coating which embrittles at some temperature.

The selective embrittlement of materials can also be used to recycle two materials which embrittle if the respective brittle temperatures are not close together. Figure (4b) depicts this situation. How great a difference is needed between the brittle temperatures before the selective embrittlement can be effectively used is not known at this time.

To increase the chance of brittle fracture the test specimens were loaded at high rates and low temperatures.

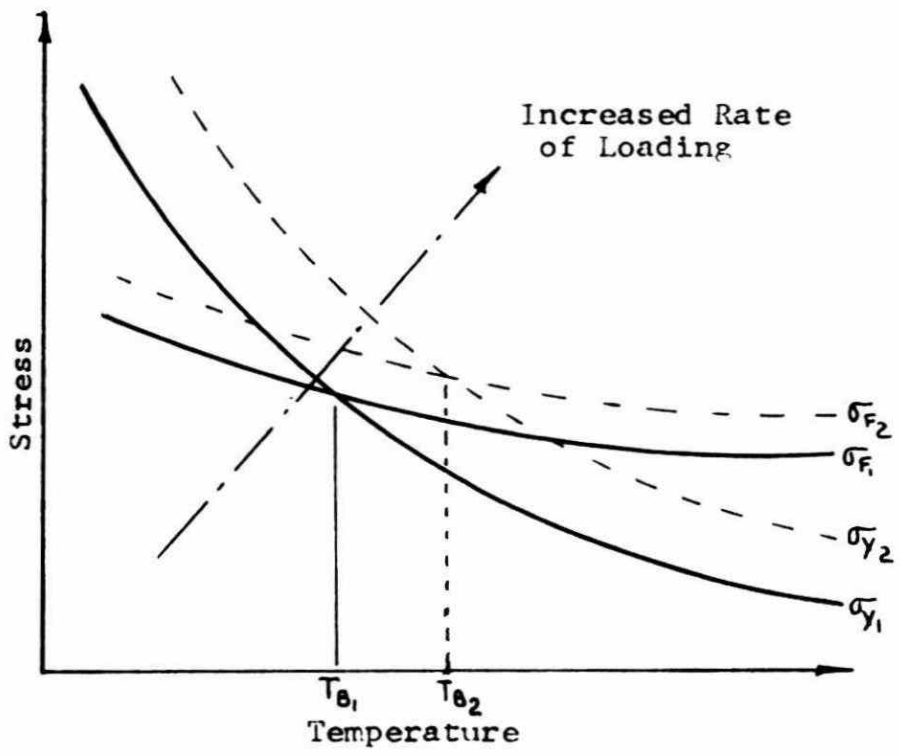


Figure 2. Effect of Raising the Rate of Loading On the Ductile to Brittle Transition.

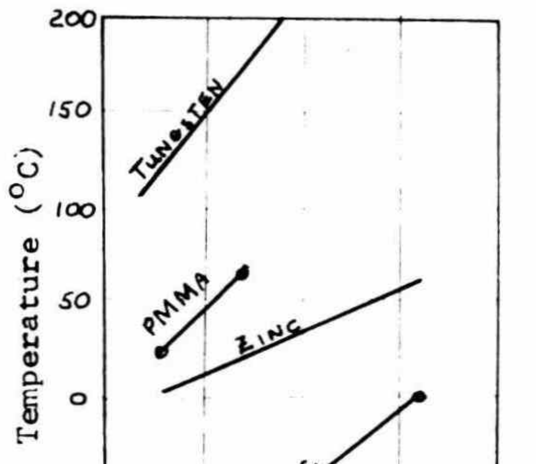


Figure 3. Brittle Temperatures for Tungsten, Zinc PMMA and PVC for Different Rates of Loading[7].

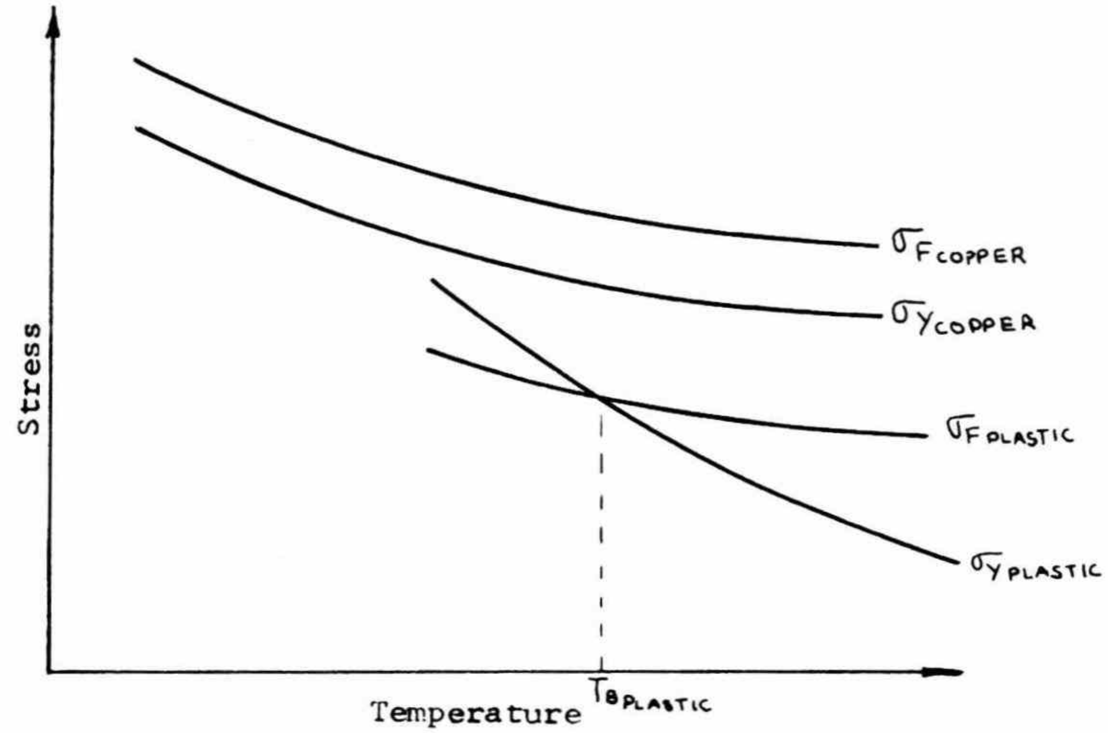


Figure 4a.

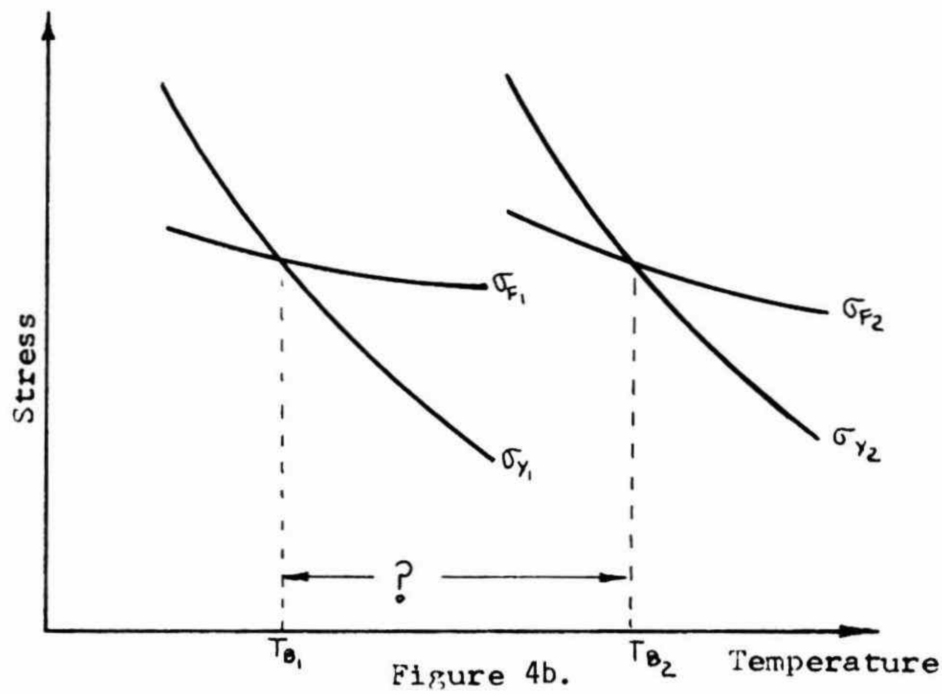


Figure 4b.

Figure 4. Yield and Fracture Behaviors of Materials Which Can Be Recycled Utilizing the Selective Embrittlement of Materials.

High rates of loading were obtained by using a hammermill to impact the specimens. Figure (5) shows a schematic and a photograph of the hammermill used in testing. The hammermill operates at 2300 rpm with a hammer tip speed of 240 ft/sec (14450 in./min) and is powered by a 3-phase 20 hp electric motor. This particular machine is a rebuilt 1942 Gehl Bros. hammermill to which several features have been added. The removable cover plate allows easy cleaning and inspection of the interior parts. The grate or so-called sieve has been cut off to ensure that ductile materials are ejected from the path of the hammers and to ensure that fibers are ejected before they wrap around the cylinder shaft.

METALS

Eighty-six of the one-hundred-and-three elements found by man are metals. Of the eighty-six metals only a few are used in significant quantities as engineering, structural or electrical materials. They are Iron (Fe), Copper (Cu), Zinc (Zn), Aluminium (Al), Tin (Sn), Platinum (Pl), Silver (Ag), Gold (Au), Lead (Pb) and Titanium (Ti). These base materials are often alloyed with other elements to provide a variety of materials each with their own unique properties.

There are several ways in which metals can be grouped. However, when describing their mechanical properties, it is most convenient to group them according to their crystal structure.

Metals have three main crystal structures: Face-Centered Cubic (FCC), Body-Centered Cubic (BCC), and Hexagonal Close-Packed (HCP). Figure (7) shows the atomic structures of each group. Most metals belong in one of these groups and are listed in Table 1. Each crystallographic structure has its own peculiar mechanical properties which allow it to remain ductile or become brittle at low temperatures.

To understand why metals of different crystal structures behave the way they do, two approaches can be taken: microscopic or macroscopic. The microscopic theories developed for slip and cleavage fracture of metals or dislocations in polycrystals [8, 9,10] are referenced but will not be discussed herein. Rather the macroscopic approach will be taken in which the unique mechanical properties of each crystallographic group will be surveyed to establish their ductile or brittle characteristics.

The Face Centered Cubic (FCC) metals are typically ductile down to -320°F (-196°C), the liquid nitrogen temperature. For this reason some of the FCC metals are used in cryogenic applications such as storage tanks for liquid cryogens. To understand

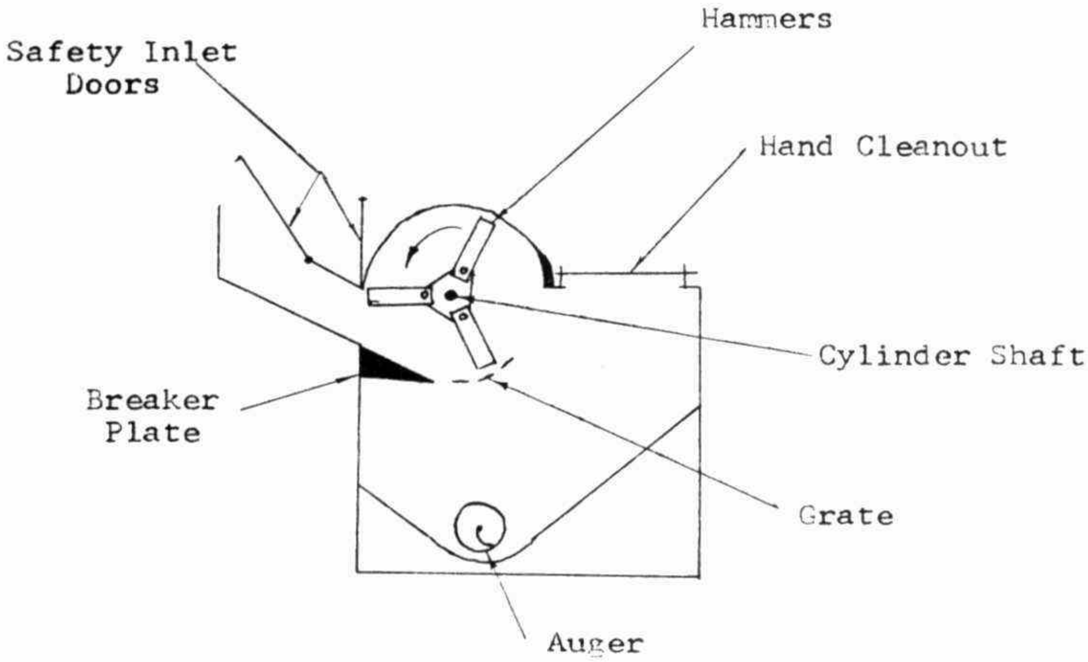


Figure 5a. Schematic of the Hammermill Used for Testing.

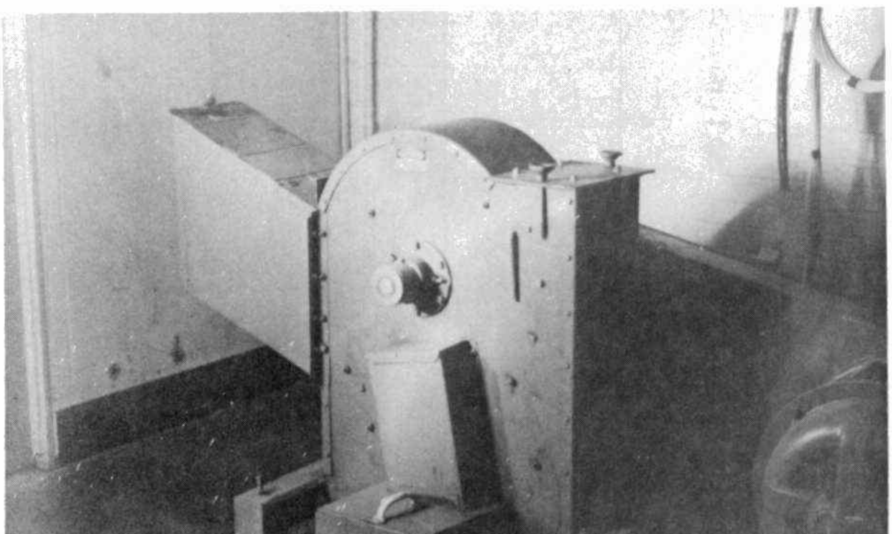


Figure 5b. Photograph of the Hammermill Used for Testing.

Figure 5.

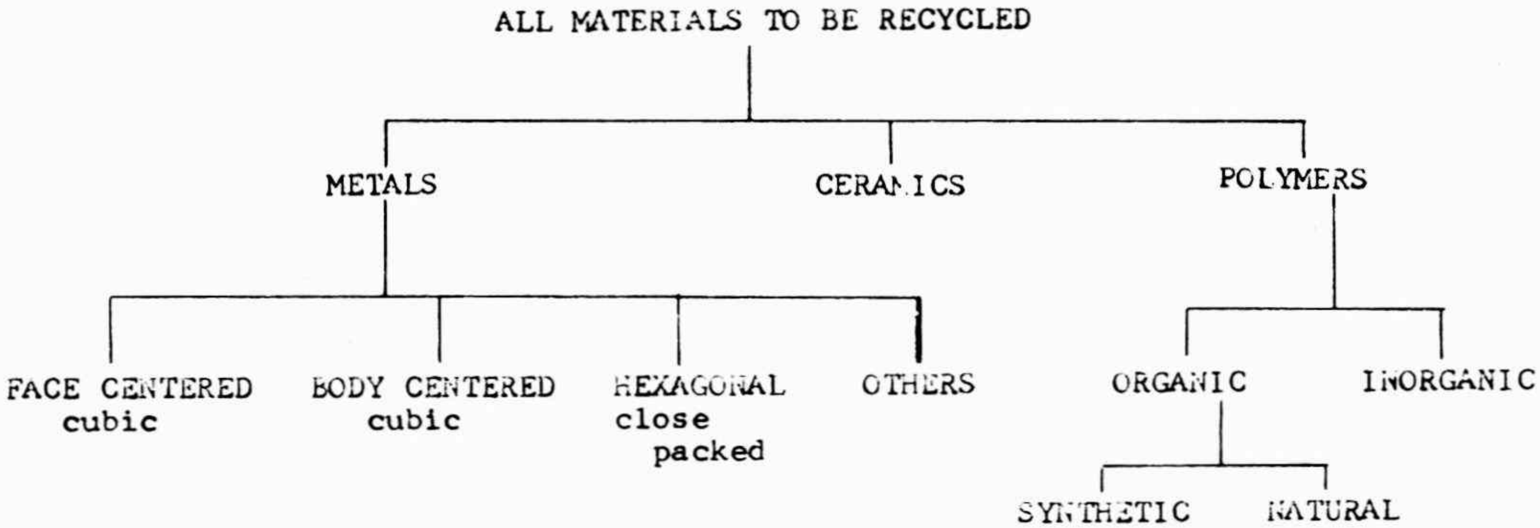


Figure 6. Grouping of Materials

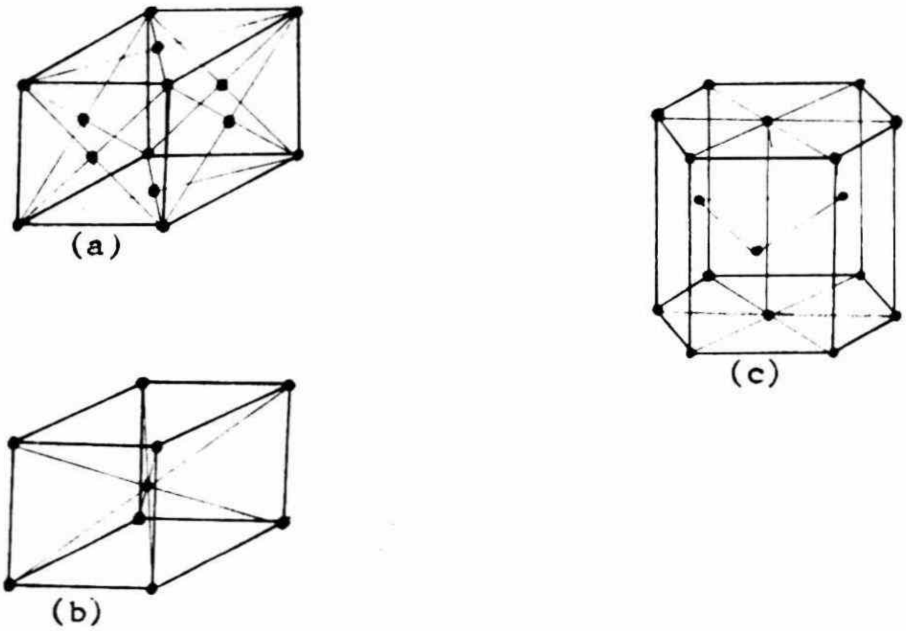


Figure 7. Crystallographic Structures: (a) Face-Centered Cubic, (b) Body-Centered Cubic, (c) Hexagonal Close-Packed.

TABLE 1
Crystallographic Groups

FCC	BCC	HCP
Aluminium (Al)	Chromium (Cr)	Beryllium (Be)
Copper (Cu)	α-Iron (Fe)	Cadmium (Cd)
Gold (Au)	Molybdenum (Mo)	Magnesium (Mg)
γ-Iron (Fe)	Tantalum (Ta)	Titanium (Ti)
Lead (Pb)	Tungsten (W)	Zinc (Zn)
Nickle (Ni)	Vanadium (V)	
Platinum (Pt)		

why the FCC metals are considered ductile, we will examine the data obtained from two tests: an impact test [11] and an uniaxial tension test [12]. The temperature-dependent curves of yield strength and tensile strength can be obtained from a series of isothermal tension tests. Similarly, isothermal impact tests can be used to obtain energy absorbed versus temperature curves. Neither of these tests have been attempted by the authors, rather published data will be referenced.

There are two instructive methods for presenting the tensile test data. Most of the published data on metals has the form of Figure (8) which shows a typical set of curves for a FCC metal. The second which is very instructive is taken from Wessel [13] and is shown in Figure (9).

Several FCC characteristics can be seen in Figure (8). The yield strength (YS) changes little when the temperature is decreased while the tensile strength (TS) increases significantly. Thus, the TS to YS ratio (TS/YS) increases as the temperature is decreased. This implies that FCC metals are able to accommodate a relatively large amount of plastic deformation before fracture, and also accounts for their extreme reliability at low temperature [15].

Examining the schematic taken from Wessel (Fig. 9) will also prove to be helpful in understanding the ductile behavior of FCC metals. Notice that the yield strength never touches the ductile fracture strength. This indicates that the FCC metals must plastically deform before they can reach their fracture strength. The cross-hatched area is present because Wessel's schematic is indicative of many FCC metals.

A FCC impact test curve is shown in Figure (10). It is typical of a metal which does not go through a ductile-to-brittle transition. Notice that the curve is relatively temperature independent and has a relatively high value compared to a BCC impact curve (see Figure 13).

In summary, the FCC metals remain ductile at low temperatures.

Body-center cubic metals (BCC), unlike the FCC metals, tend to become brittle at low temperatures. To understand why there is this difference, the uniaxial tension tests and impact test will again be examined.

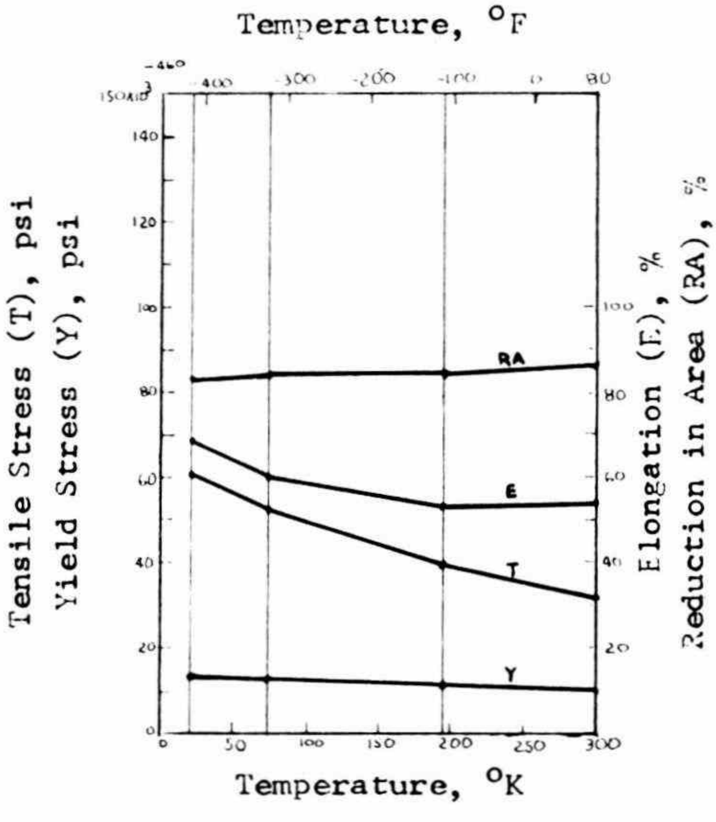


Figure 8. Typical FCC Tensile Test Curves. From (14).

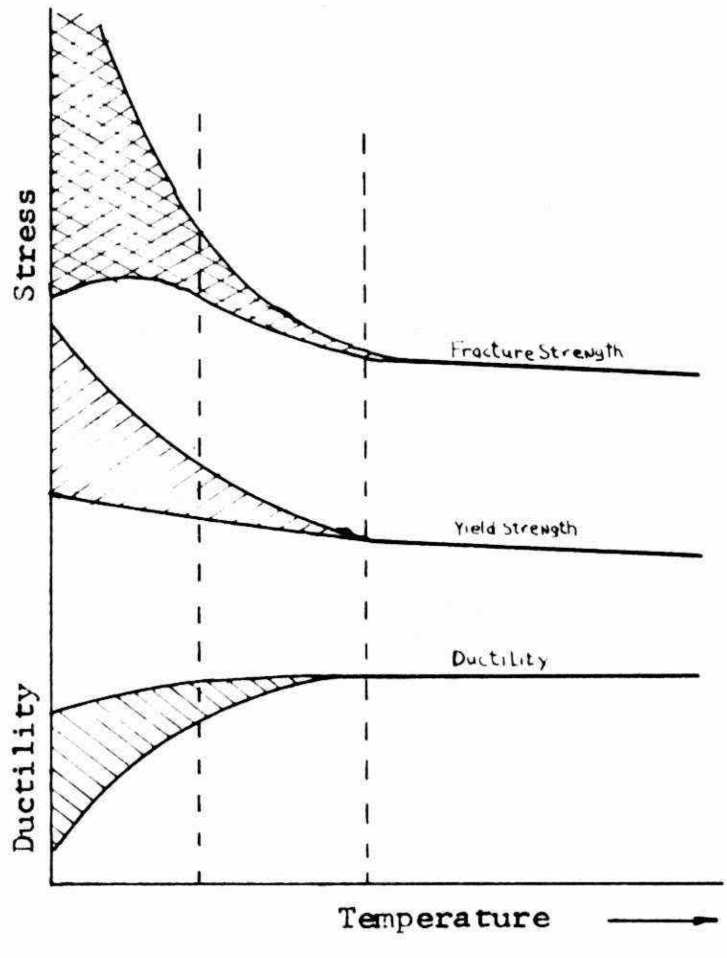


Figure 9. Wessel's Schematic of FCC Metal Behavior. From (13).

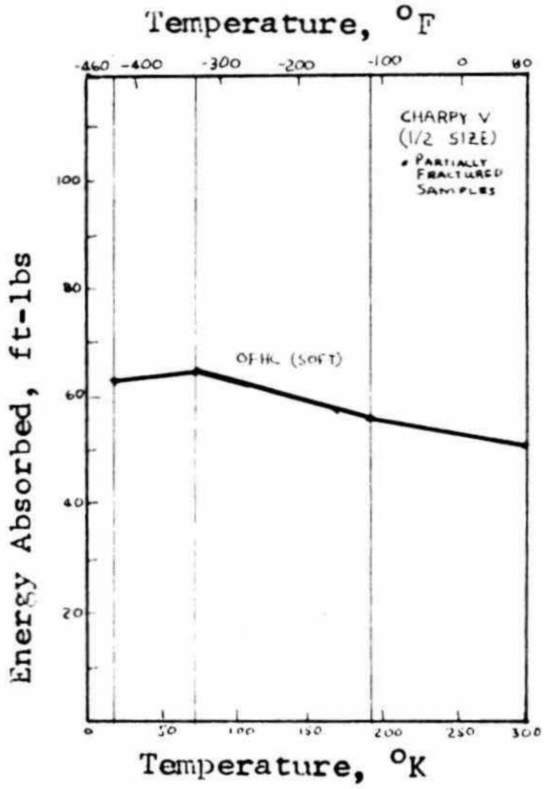


Figure 10. Typical FCC Impact Test Curve. From (14).

Typical BCC data is shown in Figure (11). There is one noticeable difference between this figure and a similar FCC figure. The yield strength is rather temperature dependent and rises faster than the tensile strength. This produces a decreasing TS to YS ratio when the temperature is decreased. This behavior is typical for a metal which will go through a ductile-to-brittle transition.

Wessel's schematic for BCC metals is shown in Figure (12) and is useful in describing the ductile-to-brittle transition in BCC metals. At high temperatures the metals behave in a ductile manner, plastically yielding before fracture. However, upon decreasing the temperature, less and less plastic deformation is experienced before fracture occurs. Finally, when the temperature falls to T_1 no plastic deformation occurs prior to fracture.

Another important feature which should be noticed is the ductile-to-brittle transition range. There is a range of temperatures in which a material could fracture in a brittle manner. This range is due to the rather pronounced differences in fracture strength that can be observed depending on the metal, its metallurgical condition, and the testing temperature [16]. The non-dimensional temperature abscissa of Figure (12) is a convenient means of drawing a schematic for many materials.

Figure (13) is representative of BCC impact data. The sharply falling impact values are typical of brittle metals.

In summary, commercially pure BCC metals will become embrittled at low temperatures.

The Hexagonal Close-packed (HCP) metals have properties which lie between the ductile FCC metals and the embrittling BCC metals. Some of the HCP metals will remain ductile at low temperature and some will not. For instance Cadmium which remains ductile down to the lowest temperatures, is very soft and liable to creep, while Zinc is highly brittle [17].

The mechanical properties of other HCP metals such as titanium and beryllium are greatly affected by interstitial impurities such as oxygen, hydrogen and nitrogen. Increasing the interstitial impurity content will increase the yield strength and tend to promote brittle fracture. Pure titanium however is an attractive material for cryogenic purposes because as the temperature is reduced, the TS/YS ratio remains constant or even increases [18].

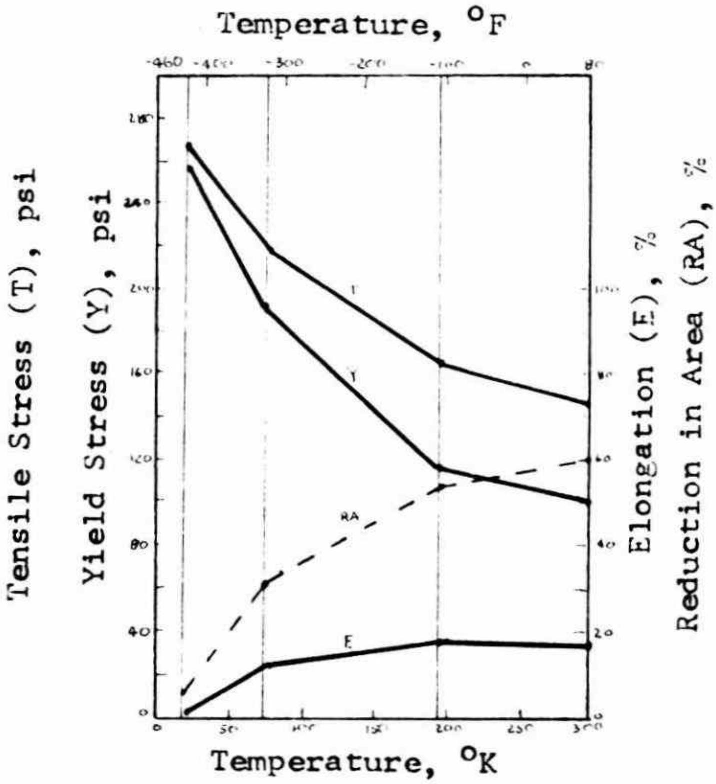


Figure 11. Typical BCC Tensile Test Curves. From (14).

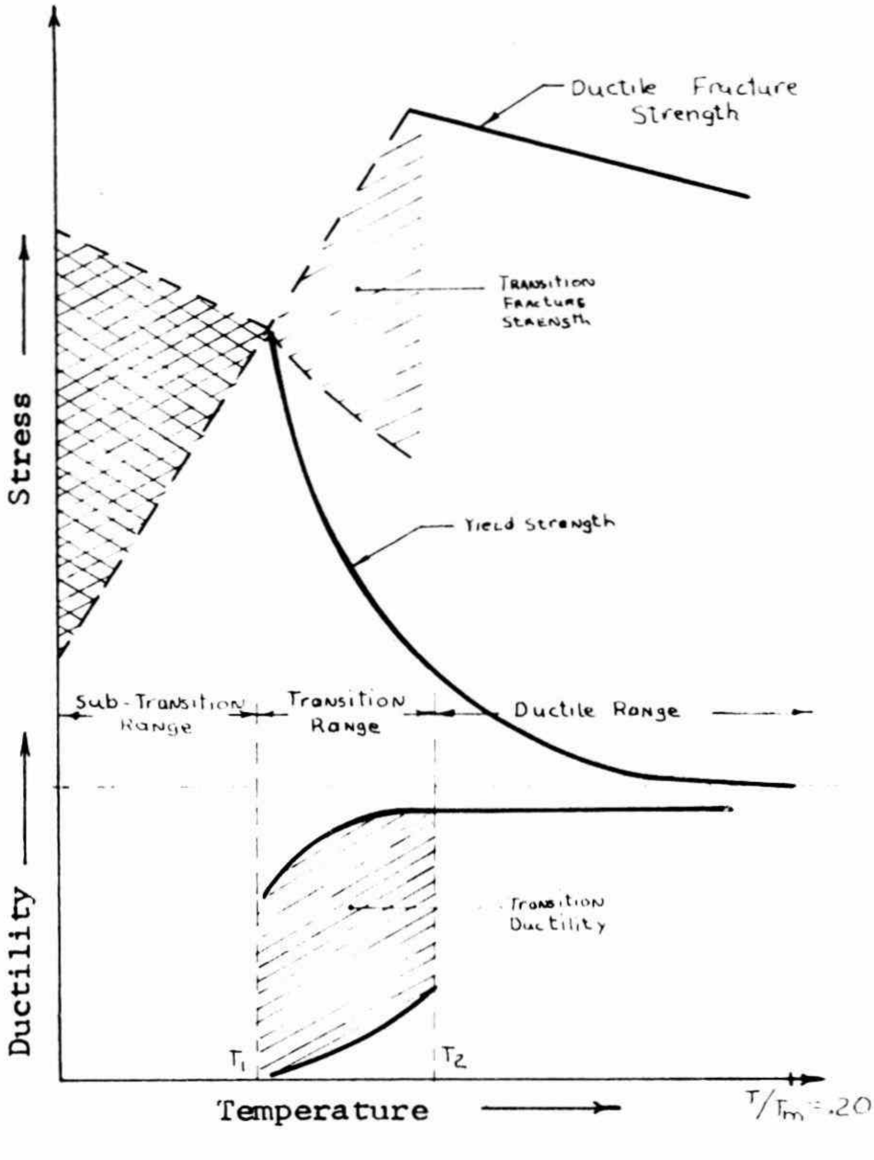


Figure 12. Wessel's Schematic of BCC Metal Behavior. From (13).

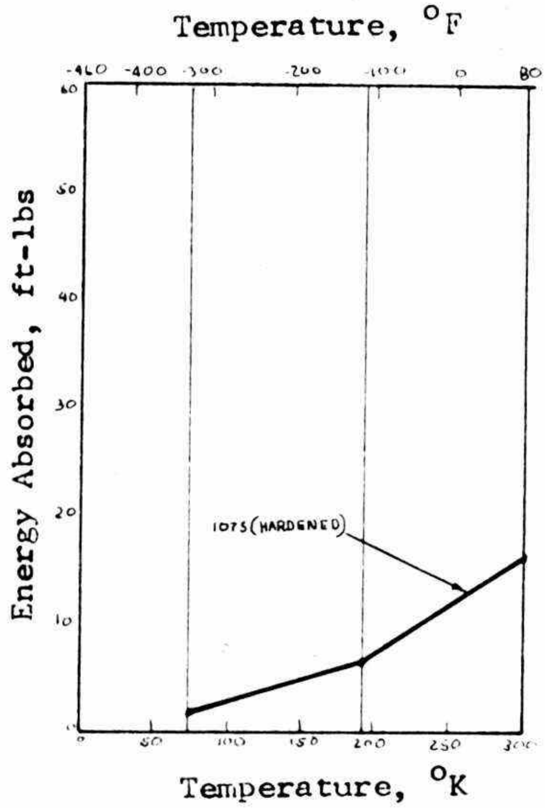


Figure 13. Typical BCC Impact Test Curve. From (14).

Steel, which is mainly Iron (Fe), can exist in either a FCC structure or a BCC structure. The differences in structure can be obtained by alloying and heat treating. The FCC steels are called austenitic steels (γ-Fe). The most widely used FCC steels are the austenitic stainless steels of the 300 series. The BCC steels are called ferritic steels (α-Fe).

So much has been published regarding the mechancial properties of ferrous materials that it would be impractical to condense all of it in this paper. However, the Society of Automotive Engineers has published a special publication, "Low Temperature Properties of Ferrous Materials," [19] which is excellent.

There are two exceptions to the preceding general discussion of the mechanical properties of metals. The mechanical properties of two copper alloys differ from those of typical FCC metals. First, there is a copper-antimony alloy which McLeon [20] has found brittle at low temperatures. Second, there is a manganese-Bronze alloy which has impact strengths which decrease as the temperature is raised. This decrease in impact strength is due to grain boundary precipitation at elevated temperatures.**

The metals which were tested came in many sizes and shapes. Specimens which would not fit into the 10"x10" hammermill entrance were cut into smaller pieces with a band saw.

More often than not however, only one specimen was received. The one-of-a-kind specimens were also cut into smaller pieces to enable testing at both -320°F (-196°C) and 70°F (21°C).

After a few metal specimens were tested it became apparent that the rebuilt hammermill originally constructed for grinding silage was not adequate for testing metals. The metal housing became dented as did the metal sieve. One specimen even pierced the metal housing. Testing continued until a specimen of cast steel fractured the breaker plate.

Since the hammermill was inadequate for testing metals it was decided to test the remaining metal samples by hand. These specimens were cut into 1/4" thick slices with a band saw. After bringing to the desired testing temperature these specimens were placed on the top of two I-beams which were two inches apart.

**The information on manganese bronze was obtained in conversations with the Falk Corporation and Professor Frank Worzola, University of Wisconsin's Metallurgical and Mineral Engineering Department.

They were then struck with a two pound sledge hammer. After impacting the specimens were evaluated in the usual manner.

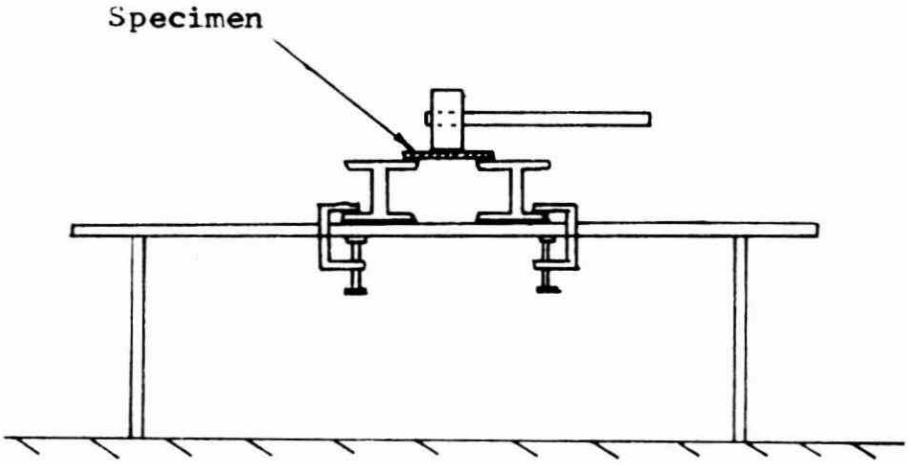


Figure 14. Hand Testing of Metal Specimens.

The results of tests done by hand are marked with the letter "h".

The appearance of the fracture-crack surfaces were used as a guide for determining whether a metal fractured in a brittle manner.

Several of the metals fractured when tested at -320°F (-196°C) but were still classified as ductile at -320°F. This was due to the appearance of the specimen after testing. For instance, the cast aluminium 356 which fractured at both -320°F (-196°F) and 70°F (21°C) had rough, torn fracture-crack surfaces at both temperatures. This type of fracture-crack surface is typical of materials which fracture in shear.

Table 2 is a classification of the metals tested.

POLYMERS

Polymers are large molecules made from many (poly-) smaller repeat units (-mers) which are held together by strong primary bonds called covalent bonds. An example of a repeat unit is

$$\begin{array}{l} CH_2\text{-}CH \\ \quad\quad\ \ | \\ \quad\quad\ CH_3 \end{array}$$

Table 2. Classification of Metals

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
ALUMINIUM					
Cast 356	SISNICAST			X	
Cast QQ-A-601	Falk			X h	
Rounds 2011-T3	RRSN			X	
Rounds 2017-T4	RRSN			X	
Rounds 2024-T4	RRSN			X	
Rounds 6061-T6	RRSN			X	
Rounds 7025-T6	RRSN			X	
COPPER					
OFHC Electrical Cane				X	

Table 2. (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Cast Bronze 80-10-10	SIGNICAST			X	
Cast Silicon Bronze	SIGNICAST			X	
Bronze SAE 65	Falk			X h	
Bronze SAE 660	Falk			X h	
Bronze SAE 660	Falk			X h	
Brass ASTM B21 (AMPCO Brass)	Falk			X h	
IRON					
STEEL					
CR 1018	RRSN		X		
SAE 1020	Falk		X		

Table 2. (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
HR 1020	RRSN		X		
SAE 1045	Falk			X h	
CR 1045	RRSN		X		
HR 1045	RRSN			X	
Mild Steel Water Pipe	--		X		
SAE 6165 (Chrome Vanadium)	Falk			X h	
STAINLESS STEEL					
17-4 PA	RRSN			X	
203 EZ	RRSN			X	
303	RRSN			X	

Table 2. (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
304	RRSN			X	
316	RRSN			X	
410	RRSN		X		
Stainless Steel 416	RRSN			X	
CAST IRON					
Ductile	G&L		X h		
Ductile (Fully Annealed)	Chromfed. Mal.	X h			
Ductile (80-55-06)	Chromfed. Mal.		X h		
Grey	Mil. Mal.	X h			
Grey	Falk		X h		

Table 2. (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Malleable	Mil. Mal.		X h		
CAST STEEL					
As Cast #1	Falk			X h	
As Cast #1 (Quenched & Tempered	Falk			X h	
As Cast #2	Falk			X h	
Cast ASTM-A148	Falk			X h	
Pelton P3	Pelton		X h		
Pelton P4	Pelton		X h		
Pelton P10	Pelton			X h	
Cast 4140	SIGNICAST		X		

Table 2. (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Cast 8620	SIGNICAST		X		
CAST STAINLESS					
SS 316	SIGNICAST			X	
SS 25-5PH	SIGNICAST			X	
Lead Base Babbit	Falk	X h			
Tin Base Babbit	Falk		X h		

which together with many other repeat units forms polypropylene,

$$CH_3-\left(\begin{array}{c}CH_2-CH\\ \qquad|\\ \qquad CH_3\end{array}\right)_N-CH_3.$$

The structural formula for polypropylene demonstrates one of the differences between metals and polymers. Notice that polypropylene can have many different molecular weights depending upon the value of N, whereas a metal has but one molecular weight. Polymers typically have molecular weights between 10^4 and 10^6 while the highest molecular weight metal is Lawrencium (LW) with a molecular weight of 103.

Polymers can be divided into two main categories: thermosets and thermoplastics. The difference between the two lies in the type of bonds which hold adjacent molecules together. In thermosets, the adjacent molecules are held together like repeat units by covalent bonds and form what is called a framework or network of molecules. Thermosetting polymers are said to be crosslinked by covalent bonds. On the other hand, thermoplastics molecules are not crosslinked but are held together by weaker secondary bonds called van der Waals forces.

The amount of crosslinking has lead to some confusion. Polymers which have many crosslinks are commonly called thermosets, but polymers with only a few crosslinks have come to have two names. Some experts refer to lightly-crosslinked polymers as elastomers, while others refer to them as thermosets. In this paper, lightly-crosslinked polymers will be referred to as elastomers. Figure 15 will be used to demonstrate the difference between thermoplastics, thermosets and elastomers.

The dots in Figure (15-1) are repeat units which are held together by covalent bonds (solid lines). In thermoplastics polymers, Figure (15-1a), the adjacent molecules are held together by van der Waals forces (dotted lines). Figure (15-1b) is a schematic of a thermosetting polymer which is highly crosslinked with covalent bonds (solid lines). Figure (15-1c) is a schematic of an elastomer with both covalent bonds and van der Waals forces holding the polymer together.

As one might expect, the different bonds affect how polymers react at high and low temperatures. Once formed, thermosets and elastomers which are crosslinked polymers will not remelt due to the strong covalent bonds present between molecules. Thermoplastics, on the other hand, can be remelted because only the

weak van der Waals forces hold adjacent molecules together.

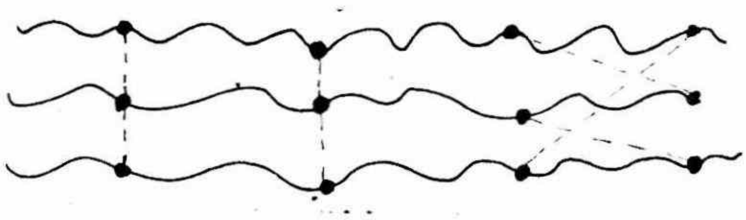


Figure 15-1a. Three Molecules Held Together by van der Waals Forces (Dotted Lines) Forming a Thermoplastic.

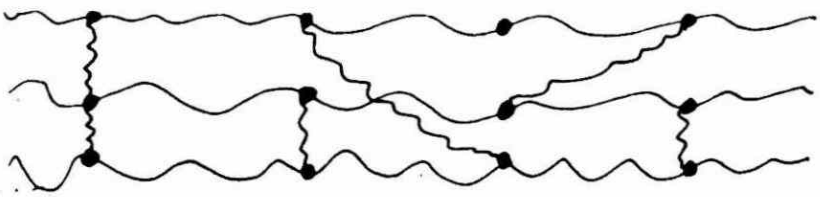


Figure 15-1b. A Network of Covalent Bonds (Solid Lines) Forming a Thermoset.

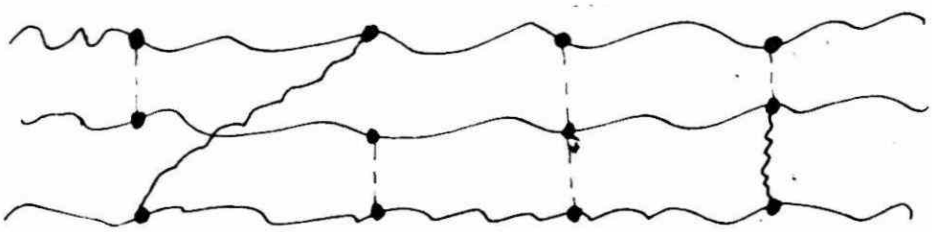


Figure 15-1c. A Lightly-Crosslinked Polymer With Both van der Waals Forces and Covalent Bonds Forming an Elastomer.

Figure 15-1. A Schematic Showing The Differences in Bonding Between Thermoplastics, Thermosets and Elastomers.

Because these polymers differ in behavior at high temperatures, different tecnniques must be used to recycle them. Once in powder or granular form, thermoplastics can be remelted and reformed into new products. Unfortunately, thermosets and elastomers cannot be remelted, so other means of recycling these materials must be found. Today ground-up rubber automobile tires,

an elastomer, are mixed with a binder and used to resurface roads and fill-road cracks. Other tires are being devulcanized (having their crosslinks chemically removed) and remolded. Using ground-up thermosets as fillers for other plastic products is also a possibility.

Unlike metals which are entirely crystalline, polymers can take on either an amorphous structure or a crystalline structure when in the solid phase.

Due to their rigid network type of structure, the molecules of thermosetting polymers cannot form a crystalline structure. The movement needed to reorganize the molecules into a crystalline structure is prevented by the covalent bonds which are formed between the molecules when curing.

Thermoplastics polymers, on the other hand, can exist in either an amorphous or a highly crystalline structure with the amount of crystallinity varying between 0 and close to 100 per cent. When cooling from the liquid phase, thermoplastics molecules can reorganize themselves into a crystalline structure because only the weak van der Waals forces are present to restrict the movement of molecules.

Crystallizable elastomers cannot crystallize as freely as thermoplastics due to the small number of crosslinks present and also due to the fact that nearly all elastomers have melting points far below room temperature, i.e., natural rubber has a melting point of -230°F (-146°C).

It should be noted that no polymer can crystallize 100 per cent and that any portion of the polymer that doesn't crystallize will have an amorphous structure.

In order to crystallize, polymers should have a symmetrical structure. Unsymmetrical or branched molecules will hinder the crystallization process. Examples of symmetrical, unsymmetrical and branched molecular structures are shown in Figure (16).

Linear polyethylene which is symmetrical will crystalize and form high density polyethylene. The branched polyethylene however, will remain amorphous or only crystallize a small amount and form low density polyethylene. Polystyrene which is unsymmetrical will form on amorphous solids.

Crystallization also depends upon the rate a polymer is cooled and the manufacturing process used to form the product.

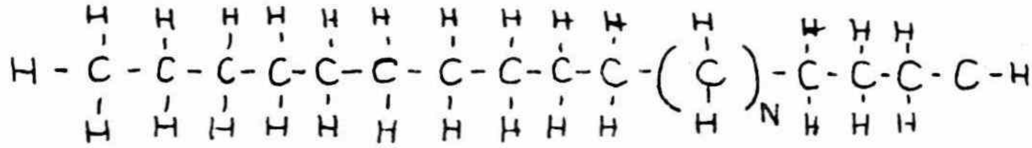


Figure 16a. Symmetrical Linear Polyethylene.

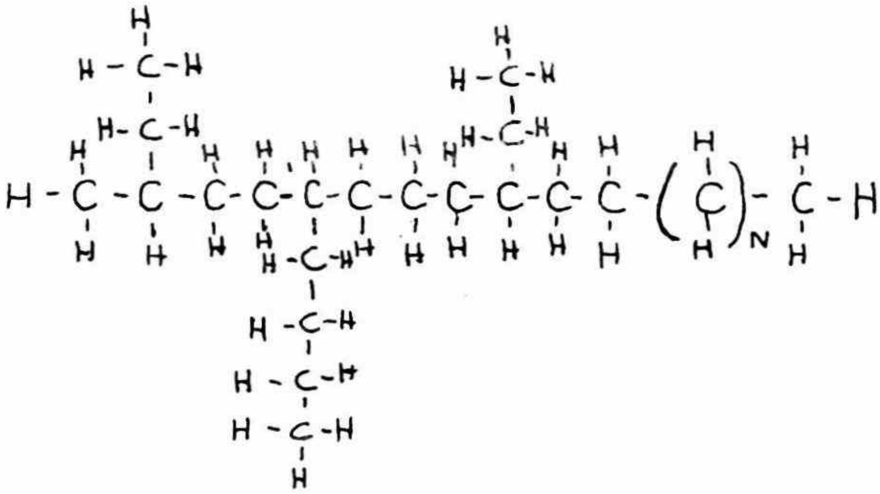


Figure 16b. Unsymmetrical Branched Polyethylene.

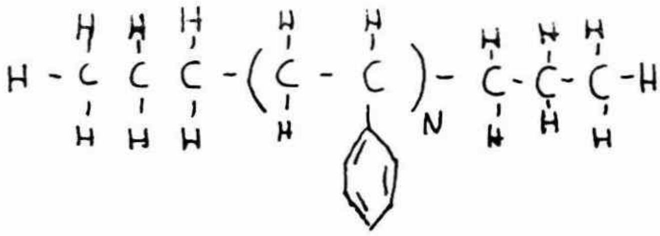


Figure 16c. Unsymmetrical Atactic Polystyrene With Benyene Side Groups Distributed Geometrically at Random Along the Chain.

Figure 16. Structural Formulas For Symmetrical And Unsymmetrical Polymers.

Figure (17) shows how cooling and processing affects the structure of thermoplastics.

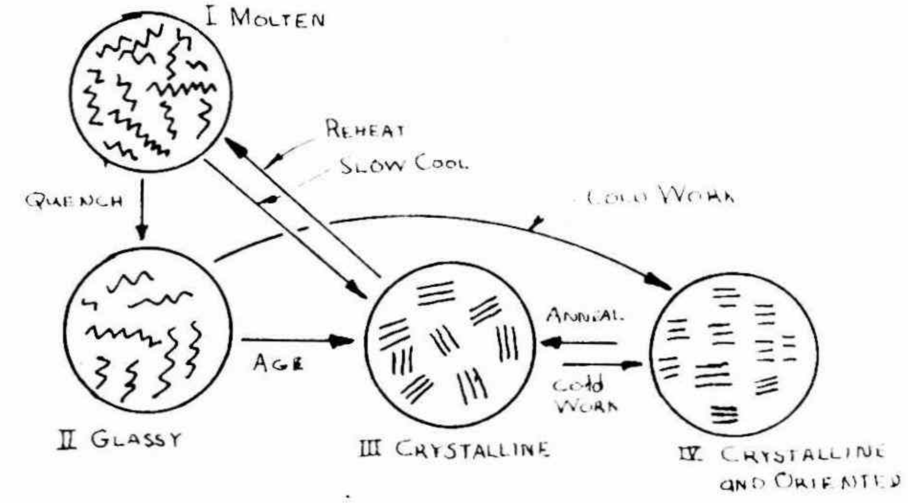


Figure 17. Thermal and Deformation Treatment of Polymers [21].

The mechanical properties of thermoplastics and elastomers are highly dependent on temperature and rate of loading whereas the mechanical properties of thermosets usually have neither of these dependencies. Even though the mechanical properties of these polymers differ, they can be portrayed on one set stress-strain curves as shown in Figure (18).

Thermosets are typically rigid polymers which fracture in a brittle manner with stress strain curves similar to curve (18a). At different temperatures thermosets still behave in a brittle manner.

At low temperatures theromoplastics and elastomers behave like thermosets and fracture in a brittle manner with stress-strain curves similar to curve (18a). However, at higher temperatures thermoplastics and elastomers start to yield and cold draw as shown in curve (18b). At still higher temperatures thermoplastics will melt and behave like a fluid with deformation stress proportional to the applied strain rate as shown in curve (18d). Elastomers, with their crosslinks preventing fluid flow, will have a rubbery behavior of curve (18c).

Temperature is not the only factor which influences the mechanical properties of thermoplastics and elastomers. A faster rate of loading will affect the mechanical properties of thermoplastics and elastomers in the same fashion lowering the temperature.

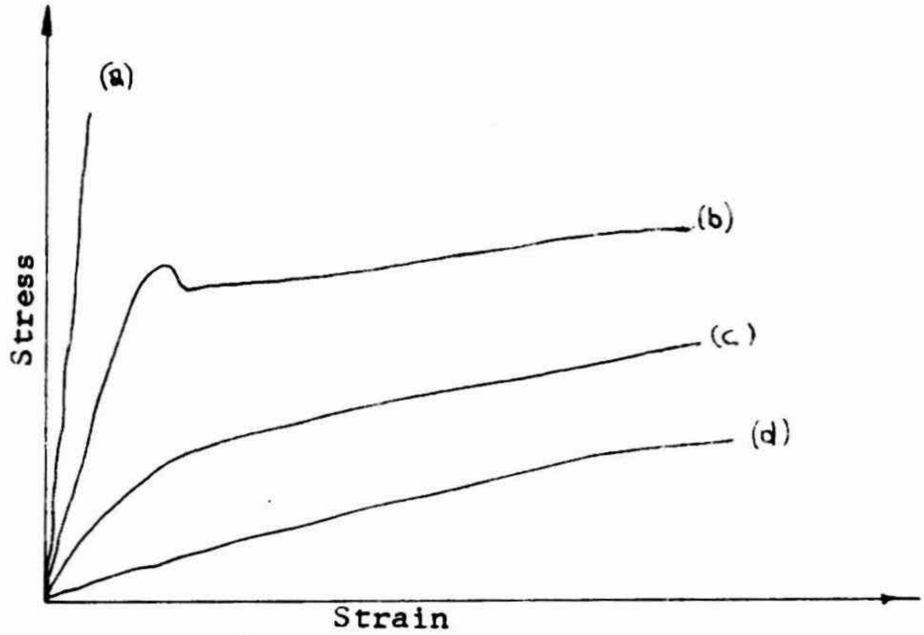
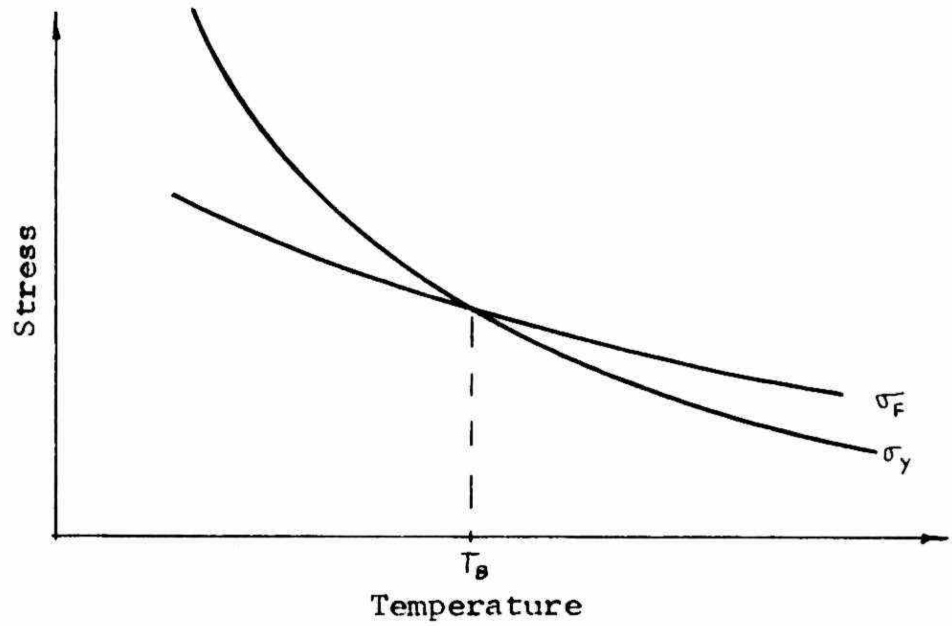


Figure 18. Mechanical Properties of Polymers.

Manufacturing processes also affect the mechanical properties of polymers. For example, nylon-6 molded gears will fracture when impacted in a hammermill at -320°F (-196°C), whereas nylon-6 film (2 mil-thick) will not [22]. This ductile behavior is typical for fibers and films and is caused by the high degree of orientation in these polymers.

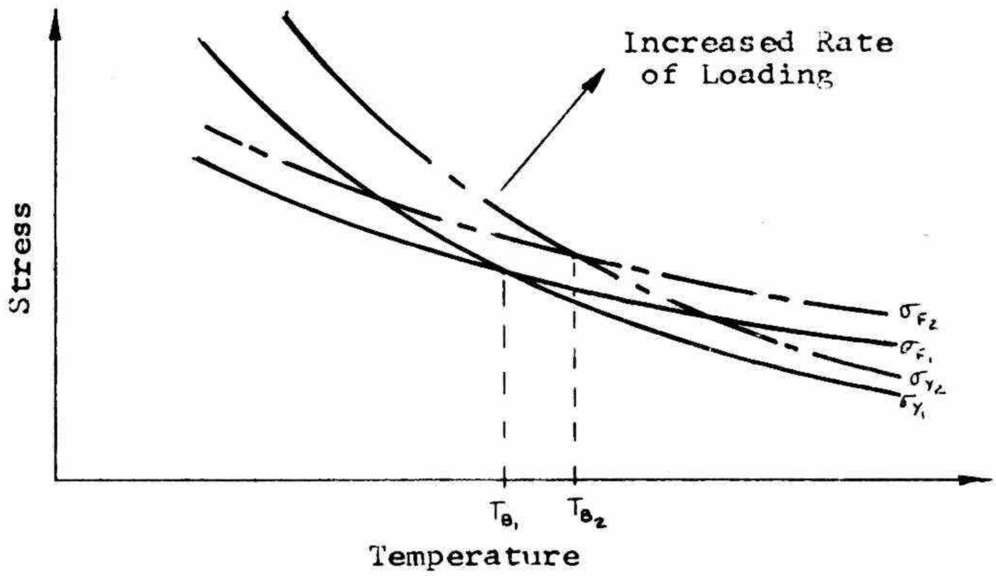
Like some metals, some polymers will go through a ductile-to-brittle transition. An explanation of the ductile-to-brittle transition in polymers can be obtained from an understanding of their yield and fracture behaviors.

In a macroscopic sense, the yield and fracture stresses of polymers act independently of one another. They act independently in the sense that they have different magnitudes and different rates of change with temperature and rate of loading [23]. Figure (19) demonstrates how the independent nature of these two stresses influences the ductile to brittle transition in polymers. Since the yield stress and the fracture stress have different rates of change with temperature, the two stress curves will intersect at some temperature, the ductile-to-brittle transition temperature (T_B). Above T_B the polymer will behave in a ductile manner, yielding before fracture. Below T_B the polymer will behave in a brittle manner, fracturing before yielding.



Ductile-to-Brittle Transition in Polymers

Figure 19.



Effects of Increased Rate of Loading on Ductile-to-Brittle Transition Temperatures in Polymers

Figure 20.

As mentioned previously, increasing the rate of loading has an effect similar to decreasing the temperature. Figure (20) demonstrates the effect of the rate of loading on the ductile-to-brittle transition of polymers. If the rate of loading is increased the yield stress will shift from σ_{y_1} to σ_{y_2} and the fracture stress from σ_{f_1} to σ_{f_2} with the overall effect of raising T_B and increasing the chance of brittle fracture.

Besides temperature and rate of loading, molecular properties and additives also affect the ductile to brittle transition. Table 3 lists several properties and additives and also lists how an increase in the properties or additives will affect T_B, the chance for brittle fracture.

Any factor which raises the yield stress relative to the fracture stress will increase the chance of brittle failure. Any any factor which lowers the yield stress relaive to the fracture stress will decrease the chance of brittle failure. For instance, if the number average molecular weight, M_N, is decreased the fracture stress will decreased while the yield stress remains the same. The overall effect of this change will be to raise T_B and increase the chance for brittle failure. Figure (21) demonstrates the affect of lowering M_N.

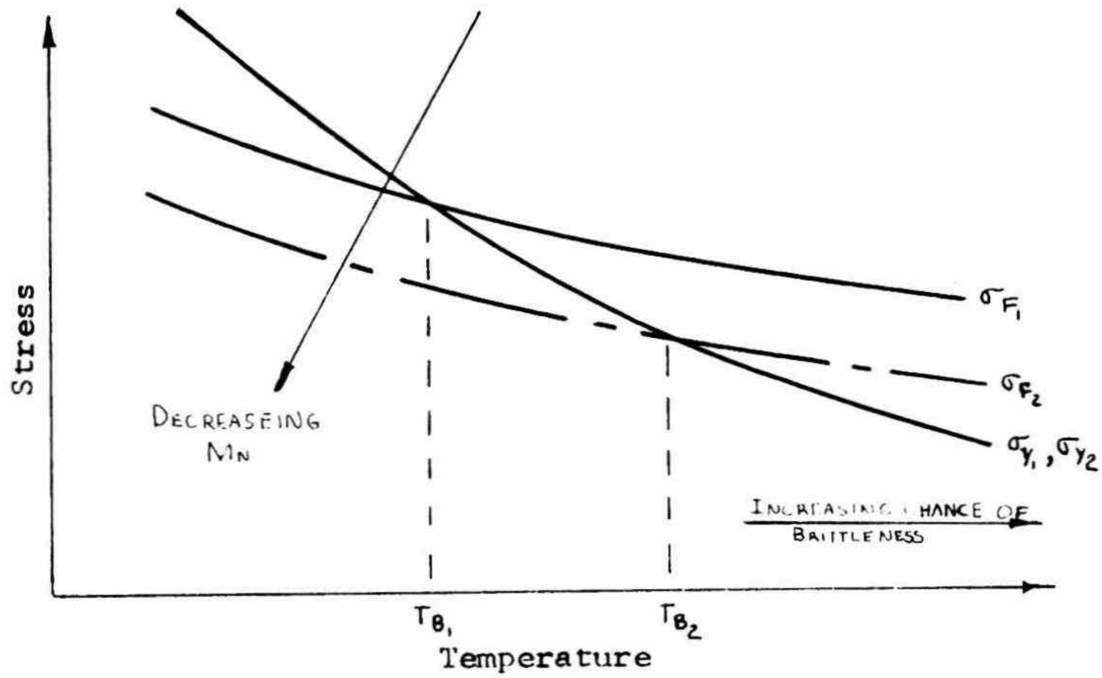


Figure 21. Effect of The Molecular Weight on T_B.

Table 3

Parameters Affecting Chance of Brittle Failure

Increased Factor	Chance of Brittle Failure	Reference
↑Temperatures	↓	24,25,26,27
↑Rate of Loading	↑	24,25,26
Molecular Property		
↑M_N	↓	24,25,27
↑Crosslinking	↑	24
↑Crystallinity	↑*	24,27
↑Orientation	↑*	24
↑Length of Linear-Side Chains	↓	24
↑Rings or Side Groups	↑	24
Additives		
↑Plasticizers	↓	24,25
↑Fibers	↑↓**	24
↑Rubbery Polymers	↓	24

*Not including films or fibers.

**Glass fibers increase yield stress so increase the chance of brittle fracture but when added to brittle resins it may increase brittle strength and so reduce chance of brittle failure.

For many common polymers--polyisoprene, polystyrene and polyisobutylene--the brittleness temperature, T_B, lies close to the glass-transition temperature, T_G. However, this is not always true. For instance, T_G for rigid pure PVC is 165°F (74°C) while T_B is -4°F (-20°C). Table 4 lists T_G and T_B for several polymers. These differences can be attributed to the definitions of T_B and T_G. T_B is defined by the technique employed to fracture a specimen, (i.e., notched bar impact test, unnotched bar impact test, etc.), whereas T_G is defined by a nondestructive type of test which measures the molecular motion of the specimen.

The notion that if T_B doesn't lie close to T_G then it lies close to a secondary lower temperature transition is also a fallacy. Polycarbonate, for example, has its lowest transition at -99°F (-73°C) (at 150 C/S) but is ductile down to -320°F (-196°C) in fracture [28].

The relationship between T_G and T_B has been stated well by Andrews [29]: "T_G and T_B are not simply related but if the yield stress σ_y is increasing rapidly in the region of T_G, as it often does for amorphous polymers, it is likely that σ_y will first exceed σ_f (brittle) in that region and T_B will then be close to T_G. If, on the other hand (for various reasons, e.g., secondary modulus transitions at lower temperatures, or broad glass transitions caused by crystallization) the yield stress is varying less rapidly with temperature around T_G and T_B is less likely to fall near to T_G" [30].

Table 4

Glass Transition and Brittle Temperatures for Polymers [31].

Polymer	T_G °C	T_G °F	T_B °C	T_B °F
PMMA	105	221	45	113
Polycarbonate of Bisphenal A	150	302	-200	-328
Rigid PVC	74	165	- 20	- 4
Natural Rubber (Polyisoprene)	-70	-94	- 65	-85
Polystyrene	100	212	90	194
Polyisobutylene	-70	-94	- 60	-76

The polymers that were tested also came in many different sizes and shapes. The samples which would not fit into the 10"x10" hammermill entrance were cut into smaller pieces with a band saw. Samples were also cut into smaller pieces if only one sample was received to enable testing at both -320°F (-196°C) and 70°F (21°C). The specimens were then brought to the desired temperature and impacted in the hammermill. Table 5 is a classification of polymers which were tested.

APPLICATIONS OF CRYOGENIC PROCESSING

With the general background of the principles of cryogenic processing let us now turn toward some specific promising application which might be of industrial importance.

The Tire-Disposal/Recycling Problem

One of the largest volume produced commodities made from synthetic polymeric materials is tires. Presently about four billion pounds of tires are being produced. Present disposal methods such as landfill, composting, ocean dumping and burning are not now adequate due to environmental considerations. Older methods of rubber recycling, using shredding and separation plus chemcial treatment to obtain reclaimed rubber, have only accounted for about 10% of the discarded tires. The high cost of shipping whole discarded tires has been the factor in limiting reclaimed rubber.

Cryogenic processing of rubber tires is a simple operation and the resulting product is in the form of particles which pr dominately fall in the 20 to 10 mesh size when screened. The fiberous reinforcement is readily separated.

Utilization of the rubber particles is now the key question. The estimated cost of the rubber particles produced by this method is about 5 cents/pound. There are a number of processing routes as indicated by Figure (22). Table 6 provides a list of suggested, specific uses of the recycled rubber particles.

Rubber has been mixed with asphalt binders for road surfaces and found to have certain favorable characteristics. A 5% mixture of rubber in asphalt has resulted in raising the softening point of asphalt, hence, less flow at high temperature. It also lowered the brittle point so less cracking has occurred at cold temperatures; plus it imparts elastic properties to the asphalt Further, a rubberized asphalt binder has also been found to hold the aggregate better.

Table 5 Classification of Polymers

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Acrylonitrile Butadienstyrene (ABS)	FLMB		X		
Acrylonitrile Butadienstyrene (ABS)	WSTRN PLSTCS		X		
Alkyd Molded Parts	PL	X			
Cellulose Acetate Butyrate	WSTRN PLSTCS		X		
Fiberglass Rod (Exten 500)	RRSON	X			
Melamine/Phenolic	PL	X			
Melamine/Phenolic	Red Rock	X			
Nylon	FLMB		X		
66 Nylon	Bemis		X		
66 Nylon	WSTRN PLSTCS		X		
Nylon Filled with Moly	WSTRN PLSTCS		X		

Table 5 (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
66 Nylon Plus Modifier	G.E.		X		
Phenolic	G.E.	X			
Phenolic	P.L.	X			
Phenolic	P.L.	X			
Phenolic	Red Rock	X			
Phenolic	Red Rock	X			
Phenolic	LAPCOR	X			
Polyacetal	G.E.	X			
Polyacetal	WSTRN PLSTCS	X			
Polyacetal Celcon	FLMB	X			

Table 5 (cont-d)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Polybutylene Terephalate	LWS	X			
Polycarbonate	G.E.		X		
Polycarbonate	Dstt		X		
Polycarbonate	FLMB		X		
Polycarbonate	WSTRN PLSTCS			X	
Polycarbonate	LWS		X		
Polyester Plus Glass Fibers	G.E.	X			
Polyethylene - low density	FLMB		X		
Polyethylene - low density	WSTRN PLSTCS		X		
Polyethylene - low density	LWS		X		

Table 5 (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Polyethylene - low density	LWS		X		
Polyethylene high density	WSTRN PLSTCS		X		
Polyethylene high density	FLMB		X		
Polyisopene (Natural Rubber)	Burton		X		
Polymethylmethacrylate (PMMA)	G.E.	X			
Polymethylmethacrylate (PMMA)	G.E.	X			
Polypropylene	Dstt	X			
Polypropylene	FLMB		X		
Polypropylene	LWS	X			
Polypropylene	WSTRN PLSTCS	X			

Table 5 (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Polypropylene Impact Grade	WSTRN PLSTCS		X		
Polypropylene co-polymer	LWS		X		
Polypropylene oxide	LWS		X		
Polystyrene	FLIXIB	X			
Polystyrene	WSTRN PLSTCS	X			
Polystyrene	LWS	X			
Polystyrene Medium Impact Grade	WSTRN PLSTCS	X			
Polystyrene High Impact Grade	WSTRN PLSTCS		X		
Polystyrene High Impact Grade	Bemis		X		

Table 5 (cont'd)

Materials	Source	Brittle at 70°F	Brittle at -320°F	Ductile at -320°F	Reference
Polysulfone	G.E.		X		
Polyurethane	G.E.		X		
Polyvinylclhoride	RRSN	X			
Silicon	Burton		X		
Vinyl	FLMB		X		

TABLE 6

Suggested Uses for Recycled Rubber

1. ASPHALT MIXES
   (Road, runways, streets, flat roofs, playgrounds)

2. FUEL
   (Stoker mixes of 10% rubber-90% coal)

3. FILTERS
   (To filter mercury from contaminated streams)

4. EROSION BREAKS
   (To prevent or retard soil erosion on slopes and shore lines)

5. ANIMAL MATTRESSES
   (Race horses and prize cattle)

6. DISTILLATION
   (150 gal. of oil; 1500 cu. ft. of gas; 40% residue per ton of tires)

7. SPORTS FIELDS
   (Football fields, tennis courts, track fields and race tracks)

8. FILLER MATERIAL
   (Thermoset plastics)

9. SOIL CONDITIONER
   (Prevents caking and provides aeration)

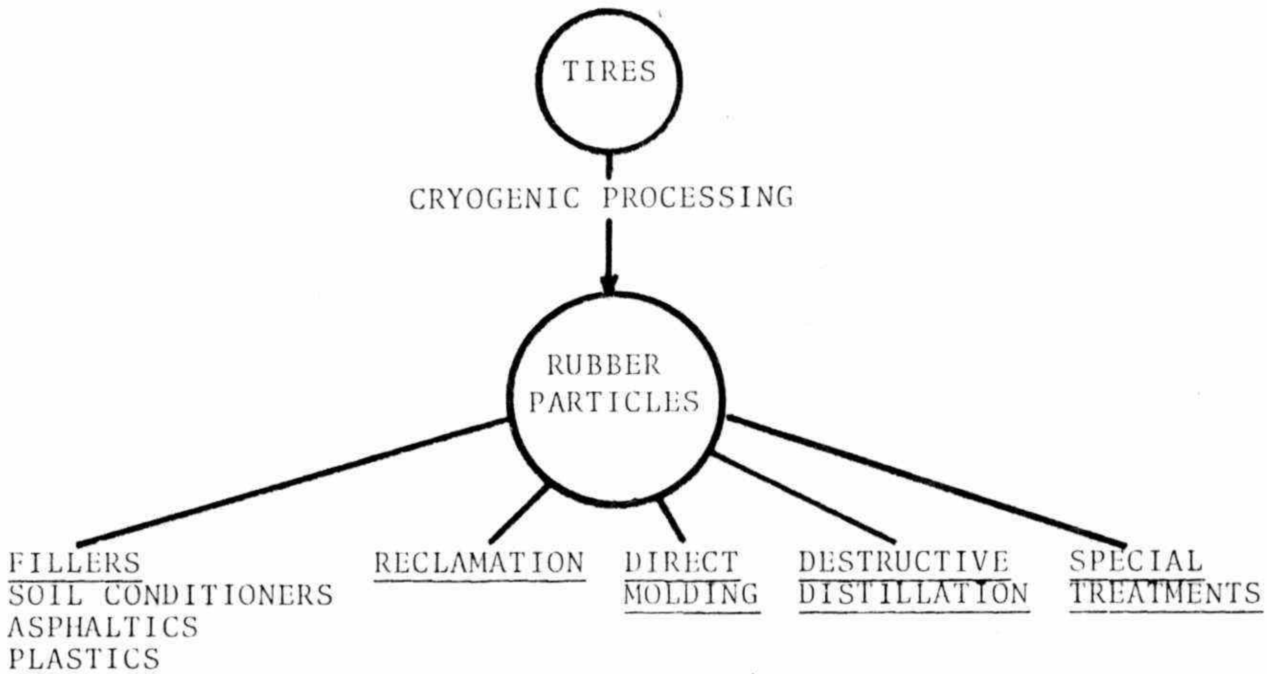


FIGURE 22

METHODS OF RECYCLING CRYOGENICALLY PROCESSED RUBBER

Although adding rubber to asphalt was first tried and patented over 130 years ago, accurate records since then have not really been kept. In the 1920's and 1930's some roads of this material were laid in Europe, with one particular stretch in New Cross, England lasting until the 1960's. It has been only recently that interest has been rekindled. It is reported that in excess of 10,000 miles of rubberized roads have been laid. Battelle Institute has in press a report on work they had done with rubberized asphalt.

The City of Phoenix, Arizona laid in excess of 208,000 square yards of rubberized asphalt on its major streets and airport aprons in the summer of 1971, with far less disruption of traffic and far less cost than with conventional materials. The city expects ten years of maintenance free service all at a substantial savings to the taxpayer [31].

Recycled rubber particles are utilized by Minnesota Mining and Manufacturing in making a base for athletic fields, tennis courss, race tracks and track fields. General Motors Research Center has found that by mixing 10 to 12% rubber with proportionate amounts of coal, a desirable fuel is developed with a BTU of 13,500 per pound of mixture. The undesirable hydrocarbons associated with the burning of tires reportedly disappears. Northern States Power Company in Minnesota ran similar tests in 1973-74. Personnel at the University of Wisconsin have been interested in the direct molding of these rubber particles mixed with certain additives such as cellulose fines and synthetic powdered resins, such as polyethylene and polypropylene. A dramatic increase in strength and elongation can be achieved by incorporation of only 10% by weight of polyolefins.

The destructive distillation of these rubber particles might be even more exciting since they can now be shipped at much less cost to distillation sites. Work has been done in evaluation of the types of yields in the distillation process. The amounts of solid residue, oil or gas produced depends on the temperature of the distillation process [32].

Work done by the Firestone Tire and Rubber Company of Akron, Ohio in conjunction with the U.S. Bureau of Mines, determined that the destructive distillation of scrap tires is technically feasible. The economic feasibility has yet to be determined; cost of shipping the tires to distillation plants is a critical point. In this study, over 150 gallons of oil per ton of tires, 1500 cubic feet of gas per ton of tires (comparable in heating value to natural gas), and 850 pounds of residue per ton of tires were obtained via destructive distillation.

Other special treatments of the particles could also be utilized such as the production of ion exchange resins. For instance, the Savannah River Ecology Laboratory at Aiken, South Carolina is researching the feasibility of using rubber particles to filter mercury from contaminated streams.

Another exciting development is the recovery of metal and insulation from used wire and cable materials. Methods now employed involve the burning or dissolution of the insulation off the metal which are slow, expensive processes and produce either oxidized and carbonized coated metal or expensive solvent recovery problems. The resulting metal often would have to be further refined. Cryogenic processing is rapid and clean and the metal is easily recovered intact.

Often times plugs, sockets and switches have high impact phenolics or phthalates as insulators which resist fracture. Cryogenic processing embrittles these materials and due to different coefficients of expansion of the insulator and metal, separation is attained more easily.

Laminates of metal and polymer sheets, which usually involve some adhesive, can be separated if there is sufficient embrittlement of the adhesive or polymer. Also delamination of polymer laminates is readily obtained if one of the polymers becomes brittle. Upon impact the embrittled polymer fragments and releases itself from the still flexible portions of the laminate.

By cryogenic processing of coated materials one can easily remove the polymer coating if the coating (normally a paint formulation) becomes brittle. Adhesion is considerably reduced especially under impact. A particular application could be the cleaning of hooks and holders for articles being sprayed or dip coated. Sometimes just dipping into the liquid nitrogen provides enough thermal stresses to fracture the coating.

The applications for cryogenic recycling have also been extended to handling entire automobiles and large metal pieces. Mr. George of Liege, Belgium, freezes the entire automobile for recycling. The freezing makes it possible to use less horsepower for the fragmenting and, even more important, aids in separating the nonferrous from the ferrous metals. Freezing does not affect the metals such as burning does, therefore, this process produces a high grade of nonferrous metal.

In addition, Stainless Processing Company of Chicago, Illinois, using cryogenic technology developed by Air Products and Chemical Inc., is processing motors, generators, and electrical equipment [33].

Perhaps the most recent study is the feasibility of removing the hair from the skin of the hog immediately following its killing. It is reported that the common practice today is to "steam cook" the hide so that the hair can be more easily removed. In so doing this, the hide is conditioned so that it can be used only for gelatin. By chilling it appears that the hair can be removed cryogenically leaving a skin suitable for leather, a much higher value product.

The cryogenic process is effective and efficient; the proper market for the separated materials can make it economical. With the priorities of our country put into proper perspective, wide use of the process can become a reality.

It would appear that the cryogenic age for recycling is upon us. It will be a challenge to be a leader in its development.

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THE ROLE OF THE MINISTRY OF THE ENVIRONMENT

IN THE DISPOSAL OF LIQUID INDUSTRIAL WASTE IN ONTARIO

This paper describes the present status of the disposal of liquid industrial wastes in Ontario and the factors leading up to present concerns. Ministry actions to deal with the problem and the subsequent implementation of the current way-bill system are discussed. The development of a proposed regulation for the control of liquid waste disposal is outlined. Finally, the proposals for treatment and disposal facilities from the private sector are discussed in the context of data generated by the way-bill system.

by

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THE ROLE OF THE MINISTRY OF THE ENVIRONMENT

IN THE DISPOSAL OF LIQUID INDUSTRIAL WASTES IN ONTARIO

W. J. Hogg

and

E. W. Turner

INTRODUCTION

Liquid industrial wastes? Hazardous wastes? Toxic wastes? What class of materials are we thinking about when we use these terms?

For the purpose of discussion in this presentation, liquid industrial wastes are arbitrarily defined as those wastes which are normally hauled away from their place of origin for disposal. In other words, wastes which, for a variety of reasons, are not treated or disposed of by the generating industry at the plant site.

We might also include the definition of hazardous materials borrowed from the Federal Government:

> "Hazardous material means any material or combination of materials which pose a substantial present or potential hazard to human health or living organisms because such materials are lethal, non-degradable, persistent in nature, capable of being biologically magnified, or otherwise cause or tend to cause direct or cumulative detrimental effects".

There are many reasons why the generators of these wastes elect not to treat and/or dispose on site. Without doubt, the prime reason is "economics". Where volumes are small or where the wastes are produced in batches at irregular intervals, it obviously does not make sense to the generator to invest capital in suitable treatment and disposal facilities. His case is further strengthened by the fact that it is an easy task to thumb through the "yellow pages" under "Waste Haulers" and to select a hauler who will be more than willing to take away the wastes. The hauler will charge for this service, usually on a cents per gallon basis, and although the cost may be high, when compared to the costs of capital investment, overhead, operation and maintenance which the generating company would otherwise have to bear, it is often a bargain.

The wastes may not be amenable to "conventional treatment" techniques and the generator may not wish to get involved in sophisticated technology which would require specialized personnel.

Other considerations may be the lack of appropriate technology or technical staff, prohibitive municipal sewer-use by-laws or just the plain reason of not wishing to get into the waste treatment and disposal business. We think it would be a fair statement to say that most industries which generate wastes and which operate waste treatment facilities would prefer to direct their technical and financial resources to productive operations.

Finally, there is the question of legal and moral obligations. Certainly, in Ontario, it is illegal to dispose of wastes in other than an approved manner. Section 40 of The Environmental Protection Act, 1971, states:

> "No person shall deposit waste upon, in, into or through any land or land covered by water or in any building that is not a waste disposal site for which a certificate of approval or a provisional certificate of approval has been issued and except in accordance with the terms and conditions of such certificates".

Section 32 of The Ontario Water Resources Act, R.S.O. 1970, states:

> "Every municipality or person that discharges or deposits or causes or permits the discharge or deposit of any material of any kind into or in any well, lake, river, pond, spring stream reservoir or other water or watercourse or on any shore or bank thereof or into or in any place that may impair the quality of the water...is guilty of an offence and on summary conviction to a fine of not more than $5,000....etc."

On the moral question, we believe many companies recognize a moral obligation not to pollute the environment and these companies are just as concerned as the Ministry over disposal of their wastes. Unfortunately, however, it appears that many companies either through ignorance or a lack of concern over the environment dispose of their wastes in the cheapest and easiest way possible, without due regard to where these wastes may end up. Part of the job of this Ministry is to educate such companies and to change their thinking.

TYPES OF LIQUID INDUSTRIAL WASTES

In Table 1, liquid industrial wastes have been classified into two broad categories; "organic" and "inorganic". This classification is convenient in that these two general categories of wastes normally require different treatment and disposal methods.

Tables 2 and 3, while certainly not comprehensive, indicate some of the types of waste in each category respectively, which are commonly encountered in Ontario. As you can see these wastes cover a very wide spectrum which is one of the reasons why treatment and disposal is a problem. We would like to point out that every industrialized country is facing this problem and despite the efforts which are being directed towards finding solutions, there does not appear to be an easy solution forthcoming.

VOLUMES OF LIQUID INDUSTRIAL WASTES IN ONTARIO

For illustrative purposes, Table 4 presents some estimates of the volumes of these wastes which must be treated and/or disposed of annually in Ontario. An accurate estimate of the volumes is difficult to make. A manual survey of all industry in the Province would be restrictive from a manpower point of view and a questionnaire approach must always be suspect because industry

itself quite often does not have accurate data on the volumes of waste disposed. An alternative approach is to estimate the volumes from a knowledge of the materials being hauled for re-use, reclamation, landfilling, shallow well disposal, etc. This approach is also unlikely to yield an accurate estimate because it does not account for illicit disposal.

Probably the only method by which an accurate estimate can be made is through a legal mechanism requiring the generators to report to the Ministry on the volumes of waste disposed. This aspect will be covered later.

Despite these drawbacks, we believe it is still possible to "guestimate" the volumes of waste using available information and some sooth-saying. Probably in Ontario at this time the total volumes of liquid industrial wastes being generated amount to some 40 to 50 million gallons per year:

- organic 15-20 million gallons/year
- inorganic 25-30 million gallons/year

Fortunately for the Ministry, this is a relatively small amount when compared to say the greater Detroit Area in Michigan which is in excess of 300 million gallons.

HISTORICAL REVIEW

Historically, in Ontario, industry disposed of its liquid wastes by either dumping them on an appropriate landfill site or by using shallow disposal wells in the Sarnia, Lambton County area. Certainly, where wastes could be reclaimed or re-used economically, this was done but this was the exception rather than the rule. Solvent recovery and waste oil reclamation are two examples which come to mind.

When problems occurred with disposal into the Detroit River Formation in Lambton County, the Ministry decided to prohibit the disposal of liquid industrial wastes into the formation. This was done by regulation which became effective in April, 1974. When the regulation was developed, it was recognized that alternative facilities would be required and the Ministry believed it had a commitment from the disposal industry to develop a cambrian disposal well in the Sarnia area as an alternative. Incineration facilities for organics had been provided earlier by the Goodfellow Group who also operated a landfill site.

Back in 1970, it was recognized that disposal of liquid wastes was becoming a problem in the Metro Toronto area and that there was need for a centralized facility to handle the wastes. The Ministry acquired property in Mississauga and invited bids from companies interested in establishing such a facility on that site. In 1973, TRICIL

Waste Management Limited officially opened an incinerator to handle organic wastes. This was Phase I of a two-phase project. Phase II was to be the construction of physical/chemical treatment facilities with access to the South Peel Sewage Treatment Plant for biological treatment. Phase II has not been developed.

The Mississauga facility was built at a cost of $1.0 million with a capacity of 15 million gallons per year. To date, it has handled a little over 3 million gallons per year.

A third incinerator was built around the same time in Hamilton by a consortium of private investors. This facility, like the Mississauga one, has not been able to realize anywhere near its potential and consequently, both are deemed unprofitable at present.

There were also numerous other small landfill sites around the Province which were approved to accept liquid wastes. The famous ski-hill in Etobicoke, when under construction, was used to dispose of millions of gallons of liquid industrial wastes.

THE PROBLEM

The fundamental problem facing the Ministry is the lack of treatment and disposal facilities throughout the Province. The shallow disposal well in the Sarnia area

should be closed down. The Beare Road landfill site operated by Metro is filled to capacity and Metro does not wish to accept any more liquids into the site. The cambrian well in the Sarnia area and the Phase II facilities at Mississauga have not been developed.

The Disposal Industry, in discussions with the Minister and with Ministry staff, stated that further investments in waste disposal facilities cannot be made until such time as the Ministry implements stringent controls on the disposal of liquid industrial wastes. Further, the industry stated that it favoured regulations as opposed to more rigid enforcement of existing legislation.

The dilemma facing the Ministry, however, was that it did not see how it could regulate the disposal of wastes until such time as suitable disposal facilities were available. In order to resolve this dilemma, the Ministry decided to construct a cambrian disposal well and expended considerable effort during 1975 working on the project. Completion of the well was deferred in the Fall of 1975 because of the government's financial restraint program.

In the Fall of 1975, the Honourable George A Kerr, upon returning to the Environment portfolio, was concerned to find that the liquid waste disposal problem had not progressed substantially since he was previously in the Ministry. Following discussions with the Disposal Industry

and recognizing the validity of their argument, the Minister made a commitment to develop an improved control mechanism regarding the disposal of liquid industrial wastes. At the same time, he made it clear to the Disposal Industry that he expected them to do their part and develop the needed facilities.

Thus the immediate priority within the Ministry is the development of a suitable control mechanism for the disposal of these wastes.

DEVELOPMENT OF CONTROL MECHANISM

By examination of the existing legislation, it was determined that Sections 14, 40 and 41 of The Environmental Protection Act provided the framework for a control program. Section 14 makes it an offence to discharge a contaminant to the natural environment which is likely to impair its quality. Sections 40 and 41 require certificates of approval for disposal sites and for waste management systems.

Based on these three Sections, it would be possible to launch a policing action against waste handlers and operators of disposal sites without further recourse to new regulations or legislation. This approach was examined and it was easily seen that a veritable army of Provincial officers would be necessary to continually check on a multitude of industrial operators, haulers and disposal

site operators. Checking would involve visiting sites, surveillance at all hours, sampling wastes and detailed laboratory analyses. The costs of such a program would be astronomical and time consuming.

Alternatively, Section 94(4) of The Environmental Protection Act authorizes the Lieutenant Governor in Council to make regulations concerning waste management.

The decision however to formulate a regulation must not be taken lightly and should be avoided if other methods to achieve the end result are reasonably available. The end result we are looking for in the liquid industrial waste situation is the assurance that all such wastes, when ultimately released to the environment, will not impair the quality of the environment. Environment in this context refers to land, water and air.

The concept of a self-policing regulation was investigated as a more effective and less costly control technique.

VOLUNTARY WAY-BILL SYSTEM

Under this concept the two parties to a disposal or transfer of liquid industrial waste would be required to report independently to the Ministry. A comparison could be made quickly by electronic data processing equipment and an exception report provided to field operations personnel for action.

A preliminary appraisal indicated that this proposal meritted a more detailed examination. Accordingly, in January of this year, a trial "voluntary way-bill" system was launched with the co-operation of industry, haulers of waste and operators of disposal sites.

A three-part form was designed (Figure 1) and distributed to haulers who were asked to provide the following information each time they picked up a load of liquid industrial waste:

- Source name and address
- Type of waste and quantity
- Time of loading
- Signature of person who releases shipment at source
- Hauler's name and address
- Method of shipment and vehicle license number
- Destination and hauler's signature

Copies of forms covering all transactions were to be mailed to the Ministry at the end of each month. Upon receipt, basic information was to be tabulated according to hauler and the forms themselves separated into waste categories.

This system has been in effect for five months using hand tabulation methods. An EDP system was not available, and consequently, only very basic information could be recorded. Periodic summaries are sent to Ministry field operations for comment and any necessary follow-up.

Co-operation from industry and the haulers in this project has been excellent considering it is entirely voluntary. To date some 32 haulers have been reporting and from this we have obtained a feel for the kind of problems which could arise using a formal system.

The data for the period January to April is summarized in Figures 2 and 3. Data for January covers a partial month and that for April is incomplete since all forms are not yet in.

The following comments and conclusions can be derived:

1. Wastes classified as sludges contributed a greater than anticipated volume;
2. Extrapolation of what amounts to three months data indicates that 32 haulers would account for 20 million gallons of waste per year. It is known that not all haulers participated, and therefore, it could be concluded that total liquid industrial waste handled in Southern Ontario could be as high as 30 to 40 million gallons per year;
3. It is surprising to note that about one-sixth of the total waste is deposited in landfill sites. This statistic should be viewed with discretion since the category entitled "other" undoubtedly includes lagoons and other interim storage facilities prior to landfill;

4. To be most useful, any formal way-bill system should report more detail on actual source and ultimate method of disposal;
5. The four broad categories used in this voluntary system should be broken down into more specific classifications;
6. The assembly of this elementary data required the services of one person approximately ten full working days per month;
7. In order to fulfill the intent of a full regulation to actually "police" the disposal of waste a more specific cross check of waste type and category of disposal facility is necessary.

PROPOSED REGULATION

A decision was made, based on experience with the "voluntary way-bill" system, to proceed with preparation of a formal regulation to control transfers of liquid industrial waste.

As a starting point, the following criteria were established:

1. The regulation must be self-policing, that is to say, control must be achieved by an exception procedure rather than constant surveillance of each transfer;

2. Independent reporting of the transfer of a waste from producer to hauler and from hauler to disposal site operator is required in order to achieve the self-policing feature;
3. The information submitted must be in a form amenable to electronic data processing;
4. An EDP program must be available to match the two sets of information from producer and disposer and report exceptions;
5. If possible, the proposed regulation should fall within the scope of the existing legislation.

Following discussions with the Ministry's Legal Branch, Field Operations, waste haulers and disposal site operators, a draft regulation has been approved by the Registrar of Regulations. In essence, it requires the hauler of waste to provide the producer of the wastes with a numbered form supplied by the Ministry. The producer is required to provide information concerning the description and amount of waste being transferred and the date, time and place of the transfer and forward a completed form to the Ministry. The hauler of the wastes is further required, when he delivers the waste to an approved disposal site, to provide the operator of the disposal site with a numbered form issued by the Ministry for completion by the operator. The operator is to provide a description and amount of the waste received, his certificate of approval

number and date and method of disposal before forwarding the form to the Ministry. Upon receipt of the forms from the producer and the disposer, it is intended to compare them, note any discrepancies and investigate such discrepancies with the operator concerned. Inherent in the regulation is the statement that no one shall deliver liquid industrial waste to any person except the holder of a Certificate of Approval for a waste management system or a waste disposal site.

At the moment, the draft regulation is under consideration for final approval by Senior Ministry management before forwarding to the Minister.

A number of interesting questions arose in translating the criteria into a workable regulation. In the interests of reducing non-essential paperwork, the definition of liquid industrial waste required careful wording to exclude from the regulation such items as sewage sludge, waste discharged legally into municipal sanitary sewers and waste disposed of legally on the site where it is produced. In particular, it became necessary to exclude waste oil or other waste liquids used for other purposes such as recycling or road oiling. Waste oil is currently under consideration in a separate project.

Legal opinions had to be developed to ensure that the regulation would hold water under The Environmental Protection Act. It was ultimately determined that the authority resided in Section 94(4)(g) relating to the

keeping of records and reporting since a generator could be reasoned as operating a waste management system. If such reasoning had not been justified, a more complex change to The Act would be necessary.

A problem not completely resolved is the description to be applied to various wastes. For example, in the course of segregating types of wastes from our "voluntary" program, we ended up with 40 different types of inorganic liquids, 46 organics and 27 different sludges. Obviously, it will be difficult to handle this kind of information even with an EDP system.

SUMMARY

In summary, it is concluded that significant gains in the control and disposal of liquid industrial wastes can be achieved by making a regulation to document and control the movement of all liquid industrial wastes. A secondary important benefit arises from the incentive this regulation will provide to the private sector for the construction of suitable liquid waste disposal facilities.

WASTE TREATMENT AND DISPOSAL TECHNOLOGY

We have just discussed the need for additional and alternative treatment and disposal facilities and reviewed the development of a control mechanism. A few words on the types of treatment and disposal facilities which can be applied to liquid industrial wastes now seems appropriate.

Technology Presently Used in Ontario

Table 5 shows the methods of treatment and disposal presently practiced in Ontario. Reclamation and re-use is limited to solvent recovery, waste oil recovery and re-use for fuel and road oiling, and pickle liquor re-use for phosphorus removal at sewage treatment plants. Wastes are presently being disposed by incinerator, landfilling, shallow well disposal and illicit means. Solidification has had limited application to date, being used to "fix" mercury containing sludges from defunct mercury-cell, chlor-alkali plants.

General Review of Technology

Table 6 indicates some of the technology which can be applied to the problem of liquid industrial waste treatment and disposal. A paper could easily be written on each of these items but a few pertinent comments at this time will have to suffice.

1. Reclamation and/or Recovery

It goes without saying that in this era of energy and resource shortage, reclamation and recovery should be practiced to the maximum. Unfortunately, in most industrialized countries, reclamation and/or recovery is governed by economics rather than need. Technology is available to reclaim or recover many materials but unless suitable economic gains can be demonstrated or unless markets are available for recovered products, there is no incentive to industry. Perhaps the incentives should be provided by governments in the way of penalties for any materials discarded which have value?

Solvent recovery and waste oil recovery appear to be viable at this time. Waste oil reclamation, eg., re-refining of used motor oils, etc., does not appear to be viable in Ontario, possibly because it cannot compete with the use of these waste oils for road oiling. For your information, the Ministry of Transport and Communications has been studying the 'Waste Oil Problem' in the Province and is expected to issue a report shortly.

Many metals can be recovered, sometimes in the form of the metal itself by simple processes but more often in the form of 'unusable' metal oxides or hydroxides. There appears to be a need for research into the recovery of metals in forms which can be more readily used by the metal manufacturers and finishers.

2. Re-Use

Road oiling using waste oil and pickle liquor use for phosphorus removal are two examples of re-use which readily come to mind. There must be, however, many other wastes which could be re-used if firm supplies in sufficient quantities could be guaranteed.

3. Incineration

Incineration needs little comment other than to point out that the operators of incinerators are finding that supplies of 'rich' wastes are scarce. Presumably this is associated with the energy crisis and the re-use of more wastes for fuel. Without adequate supplies of 'rich' wastes, the incineration of lean wastes must be supplemented with a conventional fuel which becomes expensive and which is also difficult to rationalize in view of the energy crisis.

One problem which concerns the Ministry is the lack of suitably equipped incineration facilities to handle halogenated organics. None of the incinerators in the Province is equipped with scrubbers and so these wastes frequently have to be shipped to 'Chemtrol' in New York State for disposal.

4. Incineration in Cement Kilns

This is an interesting development which resulted from Federal/Provincial studies. Chlorinated organics can be successfully burned as fuel in cement kilns with no emission problems. In fact, for certain grades

of low alkali cement the process appears to be beneficial to the cement-making process. Waste crankcase oils can also be burned without problems of lead and vanadium emissions. The value of these wastes as fuel makes this approach extremely attractive to the cement manufacturers.

5. Deep Well Disposal

The disposal of wastes through the use of deep wells has been the cause of much controversy in the U.S.A. It has been established that in one particular case, a minor earthquake was actually caused as a result of lubricating a geological fault. In Ontario, we are fortunate in having a formation known as the Cambrian Formation which is a porous sandstone lying at depths of approximately 2000 to 4000 feet below surface. This formation is relatively free of faults and, providing adequate precautions are taken in the selection of location, the design and operation of the well, this method of disposal has merit for certain types of wastes. There are certain inherent constraints on the types of waste which can be injected into this formation, and in order to minimize the risks of plugging the well, any operator is going to ensure that only suitably pre-treated wastes are injected. To some extent, there, the well is self-controlling.

The Ministry believes that disposal into the Cambrian Formation is a valid method of disposing of certain types of waste which would otherwise require extensive alternative processing. The types of waste in question are concentrated brines, inorganic salt solutions and certain types of toxic wastes.

6. Solidification

The process known as solidification or chemical fixation has been known for a number of years but has had limited application in Ontario.

The best known process is one involving the use of "silicates", normally added as liquid sodium silicate. In some respects it can be considered analagous to making concrete with liquid wastes replacing the water. In conjunction with an Ontario company, Ontario Liquid Waste Disposal Limited of Cambridge, the Ministry is running trials on a variation of this process. The purpose of the trials is to evaluate the process as a means of disposing of wastes and to provide information for developing controls on the process and on the disposal of the "solidified" material.

Initial results of the trials suggest that heavy metals are sufficiently bound to satisfy conditions likely to be encountered when the solidified materials are landfilled. The process appears to have merit in handling certain classes of inorganic wastes, however, more work is required

before the Ministry will be able to give formal approval to the process on a continuing basis.

7. Landfilling

Technically, the process of landfilling can be considered acceptable providing the landfill site is properly located, designed, constructed and operated. The major technical concern with landfilling is the severe potential for groundwater contamination. On the other hand, when considered from a land-use basis, landfill operations raise some valid concerns with the public.

The Ministry recognizes that landfilling operations for the disposal of liquid industrial wastes will probably be necessary in the short term until alternatives are available. As a general policy, however, the Ministry believes that liquid industrial wastes should receive the best practicable treatment to minimize their hazardous and toxic potential before being disposed. Therefore, in Ontario, efforts will be directed towards phasing-out the direct landfilling of liquid industrial wastes in favour of alternative methods of treatment and disposal.

Sludges resulting from industrial processes, from wastewater treatment processes and from air scrubbing operations which cannot be practicably treated further, will require landfilling. Landfill sites for these materials should be constructed on the "scientific landfill"

basis where the landfilling is done in small cells, each of which is designed and constructed to contain the wastes with a minimum of water infiltration. In this way, the types of materials disposed can be controlled with appropriate segregation and records can be kept on the exact location of the various types of wastes for future reference.

8. Treatment

As you can see from Table 6, the types of treatment utilized in processing liquid industrial wastes are generally the well-proven unit operations. Ion exchange, reverse osmosis and electrochemical processing have limited application but may be utilized more extensively as government restrictions become tighter.

TREATMENT AND DISPOSAL FACILITIES REQUIRED IN ONTARIO

With the wide variety of liquid industrial wastes generated in Ontario, there is application for each and every one of the processes listed in Table 6.

Certainly the Ministry intends to continue to promote reclamation, recovery and re-use.

There is adequate incineration capacity in the Province at present for general organics but there is need for a facility to handle halogenated organics, eg., PCBs.

The Ministry believes that there is a need for one or more cambrian disposal wells and that solidification has application providing it proves out. Associated with the cambrian well is the need for extensive pretreatment facilities and these facilities could also serve to treat wastes which are not destined for deep well disposal.

There is a very urgent need for scientific landfill sites at strategic locations throughout the Province. These sites are needed to dispose of industrial sludges and residues, treatment residues, exotic chemical wastes, etc. This need is particularly urgent in the Metropolitan Toronto and Hamilton areas.

Although the Ministry is encouraging the development of alternatives, at the same time it must be cognizant of the limitations of the available market and the potential for inadvertantly creating a monopolistic situation.

PROPOSALS RECEIVED BY THE MINISTRY

The Minister and Ministry staff have talked to many companies who have expressed an interest in developing treatment and disposal facilities in Ontario. As a result of these discussions, four proposals have been submitted to the Minister which, subject to Ministry and local government approval, could lead to facilities being available later this year or early in 1977:

a) Cambrian Disposals Limited - Chatham

This company is proposing to develop and operate a cambrian disposal well. The site selected for the well is Canborough Township, west of Hamilton. This site was selected primarily on account of favourable geological conditions but also due to its proximity to the industrialized areas. This proposal is being developed in conjunction with TRICIL Limited.

b) The D & D Group - St. Catharines

This Group is proposing to establish a reclamation, treatment and disposal facility similar to the one operated by 'Chemtrol' in Model City, New York State.

An important aspect of this proposal is the establishment of a scientific landfill site. The proposed site for this development is in Nanticoke and it is envisaged that the facility will serve local industry and possibly industry from the Hamilton and St. Catharines areas.

c) <u>Ontario Liquid Waste Disposal Limited - Cambridge</u>

This company is proposing to establish a facility for operating a solidification process to handle specific types of inorganic wastes. Approval of this proposal is subject to the outcome of the trials presently being conducted and finding a suitable site.

d) <u>TRICIL Limited</u>

TRICIL is proposing to establish a physical/ chemical treatment facility at its Mississauga site to provide for the pre-treatment requirement of the cambrian well to be operated by Cambrian Disposals Limited, and also to provide treatment for a variety of inorganic wastes. This proposal constitutes part of Phase II of the concept originally proposed for the Mississauga site and will primarily serve the greater Metropolitan Toronto and Golden Horseshoe areas.

FUTURE NEEDS FOR ADDITIONAL CONTROLS

Without entering into much discussion, it seems appropriate at this point to mention some of the areas where it is seen that future additional controls may be needed in order to establish a properly managed liquid industrial waste disposal program in the Province:

- more detailed way-bill requirements, specifically with respect to the chemical nature of wastes being hauled;
- controls to direct specific types of materials to specific locations for treatment and disposal (this will reflect more, particularly on exotic type wastes);
- guidelines or standards for the design, construction and operation of landfill sites, both for sites handling liquids directly and for those handling sludges, residues, etc.;
- guidelines for the solidification process and for the disposal of solidified materials;
- guidelines or regulations respecting the use and disposal of waste oils. Of particular concern is the issue of road oiling;

- guidelines or regulations to complement existing regulations regarding all aspects of the transportation of hazardous wastes. Both the Federal Government and the Province are working in this area. Of particular concern are spills and the ability to effectively deal with them.

FINAL NOTE

Perhaps the one point which has arisen from this presentation is the urgent need for improved management of liquid industrial waste treatment and disposal. We have come a long way in the fields of wastewater management, air management and solid waste management in recent years but the field of liquid industrial waste disposal appears to have been largely overlooked until recently.

In the future, this Ministry is going to require new industries to make decisions regarding the disposal of liquid industrial wastes prior to start-up of the plant. It will no longer be satisfactory to say that liquid wastes will be handled by an external hauler or disposal company. The Ministry will require prior detailed information on the volumes and nature of projected wastes and an indication that the selected method of disposal will be satisfactory.

It is only through tighter government controls and the full support and co-operation of all segments of industry that we are going to resolve this problem and ensure that the environment is adequately protected for future generations.

TABLE 1

CLASSIFICATION OF LIQUID INDUSTRIAL WASTES

ORGANICS:

A) RICH LIQUIDS (OILS, SOLVENTS, ETC)

B) LEAN LIQUIDS (INCLUDING LOW CONCENTRATION EMULSIFIED CUTTING OILS)

C) HALOGENATED ORGANICS

D) SLUDGES

INORGANICS:

A) ACIDS - USED AND SPENT

B) BASES - USED AND SPENT

C) NEUTRAL SALT SOLUTIONS

D) SLUDGES

TABLE 2

EXAMPLES OF ORGANIC WASTES:

Petroleum Refinery Wastes
Waste Oils
Paint and paint sludges
Spent Coolant and Cutting Oils
Semi-solids from Tanks and Lagoons
Pesticide Solutions
Cleaning Fluids
Detergent and Cleaners
Phenols
Animal Fats and Oils
Spent Solvents
Off-specification Chemicals
Monomers and Polymers from Plastics Industry
Distilling Wastes
Dairy Wastes
Tannery Wastes
Food Processing Wastes

TABLE 3

EXAMPLES OF INORGANIC WASTES:

SPENT CAUSTIC SOLUTIONS FROM PETROCHEMICAL OPERATIONS

PICKLE LIQUORS FROM STEEL PROCESSING

GALVANIZING WASTES

PLATING WASTES: - COPPER
- NICKEL
- CHROME
- ZINC
- CADMIUM
- CYANIDE SOLUTIONS

METAL FINISHING CLEANING WASTES

ANODIZING WASTES

OFF-SPECIFICATION CHEMICALS

AIR-SCRUBBER EFFLUENTS: - LIME BASE
- CAUSTIC BASE
- WATER BASE

SEMI-SOLIDS FROM TANKS AND LAGOONS

NEUTRAL SALT SOLUTIONS: - EG., SPENT BRINES
CAVERN WASHING BRINES

WATER CONDITIONING SYSTEM BLOWDOWNS

BOILER CLEAN-OUT WASTES

HEATING SYSTEM BLOWDOWN WASTES

TABLE 4

ESTIMATES OF VOLUMES OF LIQUID INDUSTRIAL WASTES TO BE DISPOSED IN ONTARIO

1970 - Industrial Market Survey of Organics in Greater Metropolitan Toronto Area

1974 - Ministry Estimate

Organics being Incinerated at three Incinerators	7-9 million g/yr
Shallow Well Disposal (Sarnia area)	10-12 million g/yr
Known Landfilling Operations	6-8 million g/yr
TOTAL	23-29 million g/yr

1976 - Estimate of Probable Waste Volumes

Organics:	15-20 million gallons/year
Inorganics: approx.	25 million gallons/year
TOTAL	40-45 million gallons/year

Ministry of the Environment

Ontario

Transport and Disposal of Liquid Industrial Waste

PLEASE PRINT CLEARLY

Source:

Company Name		
Address		
Type of Waste		Time of Loading day | mon. | yr. | hour am/pm
Quantity (lbs. gal. etc.)		
Shipment Released by	Title	

Signature ....

Carrier:

Name		
Address		
Method of Shipment bulk ☐ drums ☐ other specify ______	Vehicle Licence No.	
Destination		
Driver		Date

20-003 12/75

Driver's Signature ....

SOURCE

FIGURE 1

VOLUNTARY WAY BILL SYSTEM

LIQUID INDUSTRIAL WASTE REPORTED

BY TYPE

1000 IMPERIAL GALLONS

1976	Organic Liquid	Non Organic Liquid	Sludge	Waste Oil	Total
January (part)	321	167	76	29	593
February	524	443	839	143	1949
March	473	520	420	121	1534
April (part)	173	329	370	52	924
	1491	1459	1705	345	5000

TOTAL ALL TYPES - 5000

NUMBER OF HAULERS REPORTING - 32

June, 1976

Figure 2

VOLUNTARY WAY BILL SYSTEM

LIQUID INDUSTRIAL WASTE
REPORTED BY DISPOSAL METHOD

	LANDFILL	OTHER
JANUARY	88	505
FEBRUARY	269	1680
MARCH	343	1191
APRIL	10	914
	710	4290

JUNE, 1976

FIGURE 3

TABLE 5

PRESENT METHODS OF HANDLING LIQUID INDUSTRIAL WASTES IN ONTARIO

1) Reclamation and Re-use
2) Incineration
3) Landfilling
4) Shallow Disposal Wells into Detroit River Formation
5) Illicit Disposal into Municipal Sewer Systems
6) Illicit Disposal on Land and Into Watercourses
7) Solidification (Limited Application to Date)

TABLE 6

AVAILABLE TECHNOLOGY TO HANDLE
LIQUID INDUSTRIAL WASTES

1) RECLAMATION AND/OR RECOVERY
   (EG. WASTE OIL, METALS, CAUSTICS, SOLVENTS)

2) RE-USE
   (EG. ROAD OILING, PICKLE LIQUORS FOR PHOSPHORUS REMOVAL)

3) INCINERATION
   (WITH OR WITHOUT PRE-TREATMENT)

4) INCINERATION IN CEMENT KILNS
   (CHLORINATED ORGANICS, WASTE ENGINE OIL)

5) DEEP WELL DISPOSAL
   (CAMBRIAN FORMATION)

6) SOLIDIFICATION
   (CHEMICAL FIXATION)

7) LANDFILLING
   ("SCIENTIFIC LANDFILL")

8) TREATMENT

(UTILIZING WELL PROVEN UNIT OPERATIONS)

- EMULSION BREAKING
- NEUTRALIZATION
- CHEMICAL PRECIPITATION
- SOLIDS REMOVAL AND THICKENING
    - GRAVITY SETTLING
    - FILTRATION
    - CENTRIFUGATION
    - ULTRA FILTRATION
- CHEMICAL OXIDATION
- BIOLOGICAL OXIDATION
- CARBON ABSORPTION
- ION-EXCHANGE
- REVERSE OSMOSIS
- ELECTRO-CHEMICAL

CONTROLLING PCB DISCHARGES TO THE ENVIRONMENT

Control of PCBs must start with constraint on use and elimination of discharges from manufacturing facilities related to air, water and solid waste disposal. Control over the disposal of discarded units containing PCBs poses a significant threat that has received too little attention. Rupture of units during compaction, release through corrosion of cases or in salvage of metals by junk dealers, storm damage to outdoor transformers, recycle of paper or oil containing PCBs will continue to increase the pollution of the environment after a complete ban on the use of PCBs. Identification of specific PCB isomers is possible through solvent extraction, gas chromatography and mass spectra. Identification of the specific Aroclor source is difficult because of the fact that each Aroclor is a mixture of different polychlorinated biphenyls. A change in relative amounts of specific isomers occurs according to transport path, in biodegradability in solubility and in absorption. The greater persistence of more highly chlorinated biphenyls accounts for the preponderance of Aroclors 1254 and 1260 being reported in analysis of sediments and aquatic life.

by

NOLAN A. CURRY

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Bureau of Industrial Programs
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Mr. Curry earned his BS. ChE from Purdue University and his MChE from Rensselaer Polytechnic Institute. He has had forty-one years experience working in industry including six years on Industrial Pollution Abatement Programs. He is the author of several papers on wastewater treatment and disposal of solid wastes.

CONTROLLING PCB DISCHARGES TO THE ENVIRONMENT

BY NOLAN A. CURRY

Figures published in the Federal Register [1], show that one billion four hundred million pounds of PCBs have been manufactured since 1929. Of that figure, fifty million pounds have been destroyed and one hundred and fifty million pounds have been exported. It is estimated that three hundred million pounds are in landfills, one hundred and fifty million pounds in air, water, soil and bottom sediments. The remaining seven hundred and fifty million pounds are estimated to be contained in material and sealed units now in use. On this basis the present pollution of our air water and bottom sediments has been caused by an estimated one hundred and fifty million pounds of past production. Five times this amount is yet to be released to the environment even if another pound was never produced.

It seems necessary to address our efforts, not only to current production but to our current control of disposal of units containing PCBs.

Landfills: In the past, disposal to landfills has relied upon the adsorption by solid particles to contain the PCB's in the fill. Compaction that can rupture the case of capacitors has not been as wide spread as it is now becoming. The delay in the discharge from normally sealed capacitors depending upon the time required for corrosion to destroy the seal of the casing is temporary. Eventually the seal will be broken and the PCB's will be released from their sealed containers.

PCB's have been found in discharges from the Hudson Falls and Ft. Edward landfills used for material discarded from the General Electric plants. The chemistry of PCB's [4] show PCB's to be soluble in most alcohols, ethers, esters and hydrocarbons. The decay of organic matter in a municipal landfill produces organic compounds that can dissolve PCB's and serve as a carrier.

Platanow [2] showed that corn silage had a remarkable ability to solubilize Aroclor 1254, contained in a caulking compound. Two steers, fed silage, contained 1.37 and 0.13 ppm in muscle and 4.96 and 1.38 ppm respectively in perimuscular fat. Skrenty [3] reported that Aroclor 1254 in silo sealants (2,000 to 10,000 ppm) contaminated the silage and resulted in significant PCB levels in milk. Decaying organic matter in a municipal fill can be expected to have a similar solubilizing action.

Materials of an oily nature are not always excluded from landfills. Sludges from degreasers are frequently accepted. These will also tend to release the PCB's absorbed on solid particles. Organic materials such as hexane, are used in analytical work to release PCB's in particulate and sediment analysis and show the effectiveness of release by solvents.

Sewage treatment plant sludges generally contain significant amounts of PCBs as shown by a review of PCB levels in the environment [7].

Unless PCB's are stored in special landfills, with impermeable liners, collection of leachate and destruction of PCB's; the containment of PCB sent to the present type landfills is not dependable.

Air Discharges: Air discharges can be in the form of vapors or adsorbed on particulates. Natural removal is accomplished by fallout or condensation with rain. Methods of sampling and testing are still being developed. Pollution can originate from failure of units in use.

Vapors are more difficult to remove than particulates and are more of a problem. The vaporization rates of the different Aroclors will vary greatly as is shown in Table II. In addition the various individual components will vary.

Since the various PCB's tend to have a different vapor pressure at a given temperature, the proportion of PCB's in the vapor will be different than it was in the liquid. An example is given in figure 1 from a report by James Mieure [5]. The vapor from Aroclor 1016 is a good match for Aroclor 1221. The lower chlorinated peaks (1 and below) have increased. Peak #2 has decreased slightly. Peaks 3, 4, 5 and 6 have been drastically reduced. Thus the source of the vapors may be difficult to trace.

In general PCB vapors will tend to show an increase in concentration of the components with higher vapor pressures. The residue will tend to have more of the highly chlorinated biphenyls which have lower vapor pressures. Manufacturing plant discharges, vapors released from landfills, spills, reclaimed oils used on roads or stack emissions from burning reclaimed oils containing PCB's will all tend to show the shift in composition.

Air discharges from PCB's in recycled heating oils may be variable The lower chlorinated oils vaporize more readily and may escape the hotter portion of the fire. This is offset by the greater resistance to combustion found in the higher chlorinated PCB's. Since PCBs are resistant to low temperature incineration, household burners add to air pollution. Urban areas show more PCB pollution than rural.

PCBs adsorbed on solid particulates, would tend to be the less volatile constituents with the higher chlorination. It is seldom that the distribution of the PCBs, found in the environment, will be a good match for the original PCB composition used.

Both the particulates and vapors, condensed by cooling and rain fallout, return their load of PCBs to the soil and surface waters. It was estimated in the Chicago conference that one-half of the PCB's will eventually use air transport.

Water Discharges:

Direct discharges from manufacturing plants have occurred in significant amounts in the past. The PCB's occur dissolved in the water to a limited extent, adsorbed onto suspended solids, dispersed in droplets or dissolved in any oil or grease in the water effluent.

As droplets are adsorbed onto suspended matter the PCBs tend to accumulate in the bottom segments. PCB's vary in specific gravity from 1.2 to 1.6. As such, they are heavier than water unless present as less than fifty percent in a low density organic solvent.

When PCBs dissolve in water, the potential concentration of each component tends to reach an equilibrium depending on its specific solubility (see Table IV). The solubilities vary according to the amount of chlorination and to the specific location of the chlorine atoms on the biphenyl molecule. Solubilities vary from 5.9 ppm for 2 mono-chlorobiphenyl to 0.007 ppm for 2, 2', 3, 3', 4, 4', 5, 5' octachlorobiphenyl. The net result can be shown in figure 2 taken from the report of James Mieure. When Aroclor 1016 is shaken up with water and the undissolved PCB's removed, the amount dissolved in the water as measured after hexane extraction shows a distribution of peaks more nearly resembling Aroclor 1221 than 1016. A measurement of the undissolved residue would show a reduction in relative concentration of the mono-chlorinated biphenyl, resulting in a relative shift towards identification as a more highly chlorinated biphenyl.

Bottom sediments frequently start as settleable or suspended solids in water. Dr. Munson[6] showed that a major portion of the PCBs from the headwaters of Chesapeake Bay was present adsorbed on the suspended matter in the water.

In the survey of PCBs at the Hudson Falls Plant of General Electric, about 38 ppb of PCB was found in the inlet water taken from the Hudson River. A sample, with the suspended matter removed, showed less than one ppb of PCB. Normally, water in the river is less than 1 ppb of PCB's.

In the surface water run-off from land, contaminated by PCB spills or air fall-out, the amount of PCB measured in discharges from G.E. property ran higher in suspended matter as well as PCB's during and immediately after a rain.

Thus past discharges of PCB's tend to cycle from air to water to soil with minimal amount undergoing destruction to non-toxic compounds. Most of the degradation is in the biphenyls with lower number of chlorine atoms. As a result, the build-up in the environment tends to be concentrated in the penta-, hexa- and hepta- chlorinated biphenyls. Most of the contamination in fish in the Hudson is reported as Aroclor 1248, 1254 and 1260. These reports reflect the concentration in the aquatic food chain of the more persistent PCBs. Reports on excretion of PCB's by aquatic organisms show mainly lower chlorinated biphenyls. In New York State since 1973 most of the PCB's reported being used are Aroclor 1016 which contains less than 1% of the biphenyls con-

taining five or more chlorine atoms.

Case Histories of Discharges from Sealed Units

Case 1: Central Hudson Electric and Gas has had three failures of power capacitors from a series of sixty-three from one manufacturer since January 15, 1976. The capacitors were 100 K_{VAR} with a voltage rating of 76,204. Two were part of a bank of eight capacitors. The thrid was in a different location. Cases had apparently ruptured because of a thermal runaway. PCB's were spotted running down the poles.

Remaining capacitors on the poles were de-energized and the company is replacing the 60 capacitors with another type that do not contain PCB's. The soil at the base had strong fumes of PCB's. Samples of soil gave the following analyses:

No. Units failed at site	Surface	2 ft. below surface
1	1,900 ppm	1,400 ppm
2	18,000 ppm	890 ppm

Earth worms sampled at the first site showed 230 ppm-dry weight.

The manufacturer has been asked to check to determine if failure was a fault in the new design or a problem in production of the series involved. A questionnaire (Appendix I) has been sent to all power companies in the state to check on the possibility of further occurrences of a similar nature.

Case 2: Car accidents are numerous in which the power pole is snapped and the transformer ruptured. While transformers on utility poles may not contain PCB's, most capacitors are of the PCB filled type.

Case 3: During a late winter sleet storm, many power poles were snapped off at the base. One repair shop that was inspected showed several ruptured transformers leaking PCB's.

Case 4: In rural areas, transformers, capacitors and insulators are used as targets by boys with rifles or by frustrated hunters. Any units filled with PCB's can lose much of their impregnant as a result.

Case 5: Capacitors removed from residences or buildings are disposed as trash. Inquisitive youngsters will sometimes open them up out of curiosity or to salvage material. The PCB is normally dumped down the nearest drain. A friend recently reported having two ruptured fluorescent ballasts leaking in his basement.

Case 6: Transportation of large transformers may result in damage in transit with loss of PCB's. A large unit may contain 1500 gallons. One such occurrence is known in Tennessee, another near Seattle. The latter was being loaded on a ship when a faulty sling dropped the transformer, rupturing the casing.

While the argument for continued use of PCBs is based on its low flammability as well as its reliability, use in unprotected locations

subject to damage with increased possibility of discharge of PCB indicates the need for further limitation of use in such cases. The six cases listed are examples showing the possibility of pollution from units now in use.

Future Requirements for PCB Use and Disposal

1. Continued search for a PCB substitute is essential.
2. Uses of PCB filled power units in the open should be banned. Units in which flammability is not a major consideration should be changed to a non-PCB impregnant. Excessive danger of rupture and spillage of PCB is sufficient reason for further limitation on use.
3. Large transformers in use where flammability requires PCB should be placed in a vault or dike where containment is possible and PCB can be destroyed. There should be no drains in area to permit discharge to sewers.
4. Any disposal of PCB filled units, must be to a chemical type of landfill with an impervious liner. Water should be kept from the fill to reduce amount of leachate. Any leachate must be collected and subjected to high temperature incineration or equivalent to destroy PCBs. Dwell time of 3 seconds at $2000^{\circ}F$ or $1\frac{1}{2}$ seconds at $2200^{\circ}F$ will destroy PCB's.
5. Opening of cases by junk dealers to salvage metal content should be banned.

6. Any disposal of PCB's to heating oils, to recycled oil or for use as road oils should be prohibited. Oil recycling plants should be monitored for PCBs in the oil or in the air emission in reprocessing.
7. Paper recycling plants should be monitored and required to reject any source of wastepaper high in PCB's (i.e. - carbonless copy paper from old files).
8. From manufacturing plants, all process water will be required to be given best practical treatment. Based on evidence in the case of New York State vs. G.E., removal of PCB's to a limit of 1 ppb seems possible. After removal of suspended material and of oil, passage through a carbon column with about one hour contact time seems required.

   All solid waste (suspended solids with absorbed PCB or solid material used to absorb PCBs) must be placed in a chemical type landfill with an impervious liner and means to prevent access of ground, surface or rain water. Leachate must be collected and subjected to high temperature incineration or a suitable equivalent, if developed. Regeneration of adsorbent such as carbon must be provided with afterburners for high temperature destruction of PCB's. Temperatures for PCB destruction will destroy activated carbon.

9. Materials contaminated by spills or rupture of units will require the same care in handling as the manufacturing plant wastes.

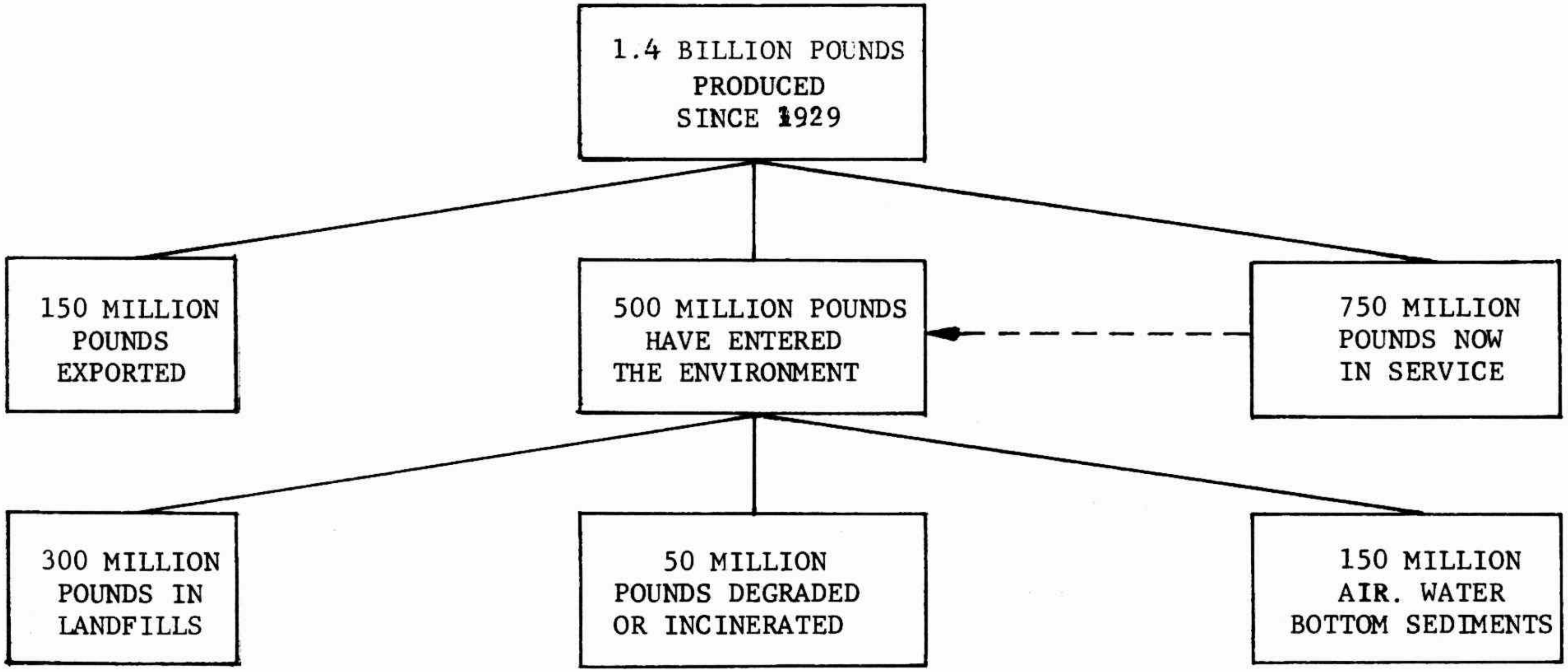
10. Any dredging of bottom sediments must provide for minimal release of PCB's to the water during operation or in the disposal of the solids.

Acknowledgement: The assistance of Mr. S. Pagano in editing and Mrs. Susan Myers in preparation is gratefully acknowledged.

1. Federal Register 41 (64) 14134 (Thursday, April 1, 1976) "PCB containing wastes (Industrial Facilities)
2. Platanow, N.S. et al. Can. Vet. Journ. 12, 115 (1971)
3. Skrenty, R.F. et al. Bull. Environ. Contam. Toxicol. 6, 409 (1971)
4. Hutzinger, O., Safe, S. and Zitko, V., The Chemistry of PCBs CRC Press (1974)
5. James P. Mieure, "Characterization of Polychlorinated Biphenyls" National Conference on PCBs (Nov. 19-21, 1975)
6. Munson, James, Paper, National Conference on PCB's (Nov. 19-21, 1975)
7. "Review of PCB Levels in the Environment", Office of Toxic Substances, EPA, (Jan. 1976)

TABLE I

PCB HISTORY IN THE U.S.



Federal Register Vol. 41(64) 14134 (Thursday April 1, 1976)

TABLE II

Vaporization, Rates of Aroclors @ 24 hrs. at $100^{o}C$

Aroclor	Vaporization Rate $gr/cm^2/hr$
1221	0.00174
1232	0.000874
1242	0.000338
1248	0.000152
1254	0.000053
1260	0.000009

From Chemistry of PCBs page 17

TABLE III

Melting points of various poly chlorinated biphenyls (PCB)

Mono	MP ^{o}C
2	34
3	16-17
4	77.7
Di	
2,3	27.7-28.2
2,4	24.1-24.4
2,5	22-23
2,6	35-36
3,4	49-50
3,5	31-36
2,2'	60.5
2,3'	oil
2,4'	32-46
3,3'	29
3,4'	oil
4,4'	148-149
Tri	
2,3,4	101-102
2,3,5	41
2,3,6	*
2,4,5	78-79

Table III continued

Tri	MP^oC
2,4,6	46-62.5
2,2',3	28.1-28.8
2,3,4'	73-73.2
2,4,4'	57-58; 206-207
2,2',5	43-44
2,3',5	40-40.5
2,4',5	63.5-67
2',3',4	54-66
3,4,4'	86.8-87.8
2',3,5	86.8-87.8
3,4',5	58
Tetra	
2,3,4,5	92-92.5
2,3,5,6	79
2,3,4,4'	142
2,4,4',5	125
2,2',4,6	*
2,4,4',6	*
2,2',3,3'	119.5-121.5
2,2',3,4'	68-70
2,2',3,5'	46.5-47
2,2',4,4'	41-83

Table III continued

Tetra	$MP^{o}C$
2,3',4,5'	65-68.5
2,3',4,4'	124-127.5
2,2',5,5'	86.5-89
2,3',4',5	104
2,2',6,6'	198
3,3',4,4'	173
3,3',5,5'	164
Penta	
2,3,4,5,6	123
2,3,4,4',5	98-99
2,2',3,4,5'	111.5-113
2,3,3',4,4'	101-105
2,2',3',4,5	81-82
2,2',4,5,5'	76.5-77.5
2,3',4,4',5	82-107
Hexa	
2,2',3,4,5,6	134-137
2,3,3',4,5,6	97-100
2,3,4,5',5,6	160-165
2,2',3,4,4',5	77-78
2,2',3,5,5',6	100-101

Table III continued

Hexa	MP°C
2,2',3,3',4,4'	145.5-152
2,2',3,4,4',5'	78.5-80
2,2',3,3',5,5'	128-129
2,2',3,3',6,6'	114-114.5
2,2',3,4',5',6	oil
2,2',4,4',5,5'	103-138
2,2',4,4',5,6'	oil
2,3',4,4',5,5'	*
2,2',4,4',6,6'	112.5
3,3',4,4',5,5'	201-202
Hepta	
2,2',3,4,5',6	147-150
2,3,3',4,4',5,6	116-118
2,2',3,3',4,4',5	134.5-135-5
2.2',3,3',4,5,6'	130.5-130.7
2,2',3,4,4',5,5'	109-110
2,2',3,4,4',5,6'	152-153
2,3,3',4,4',5,5'	162-178
Octa	
2,2',3,3',4,4',5,5'	152-160
2,2',3,3',4,4',6,6'	132
2,2',3,3',5,5',6,6'	161

From the Chemistry of PCB's

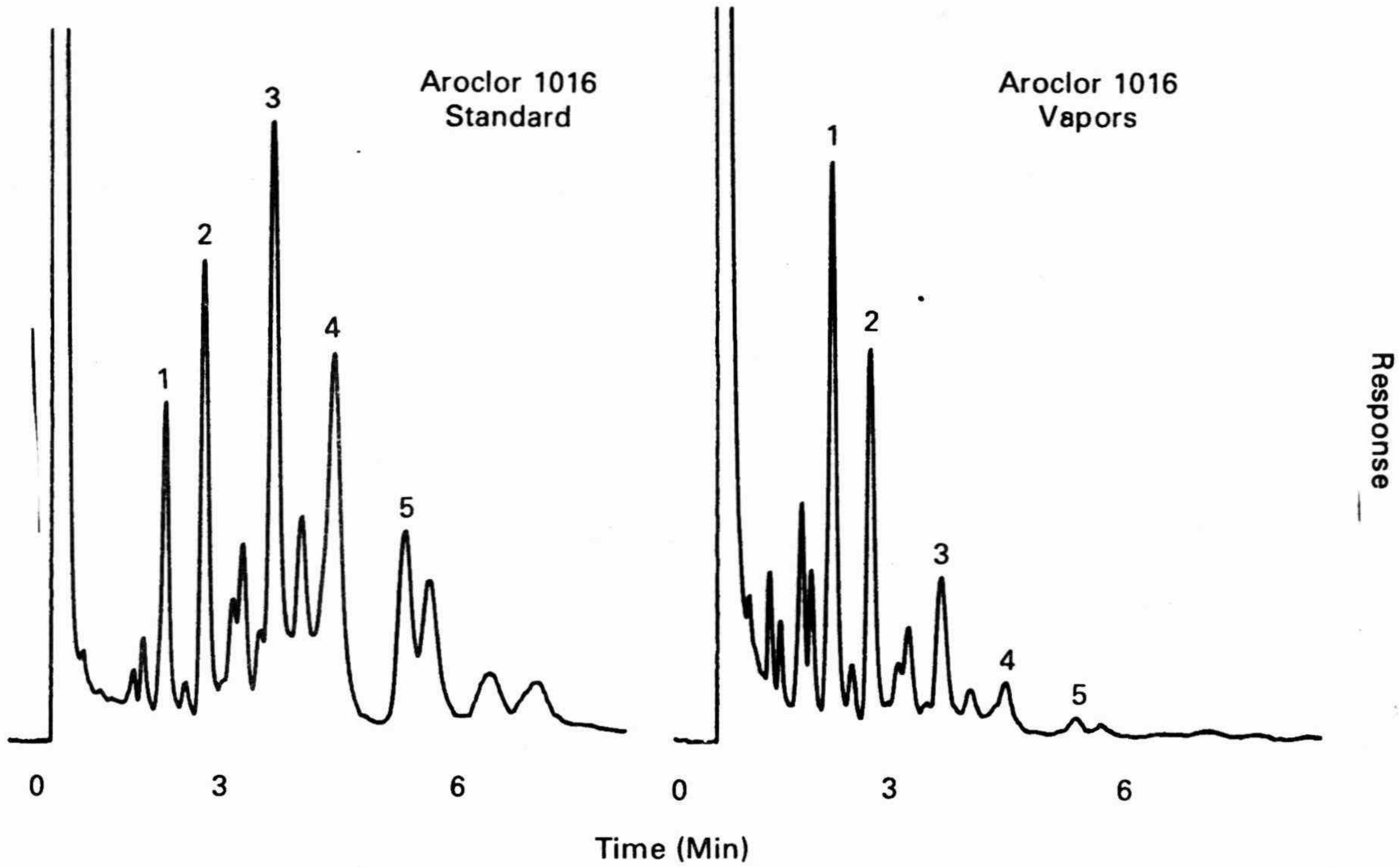
TABLE IV

Solubility of Chlorobiphenyls in Water

Compound	Solubility mg/l (ppm)
Monochlorobiphenyls	
2-	5.9
3-	3.5
4-	1.19
Dichlorobiphenyls	
2,4-	1.40
2,2'-	1.50
2,4'-	1.88
4,4'-	0.08
Trichlorobiphenyls	
2,4,4'-	0.085
2',3,4-	0.078
Tetrachlorobiphenyls	
2,2',5,5'-	0.046
2,2',3,3'-	0.034
2,2',3,5'-	0.170
2,2',4,4'-	0.068
2,3',4,4'-	0.058
2,3',4,4'-	0.175

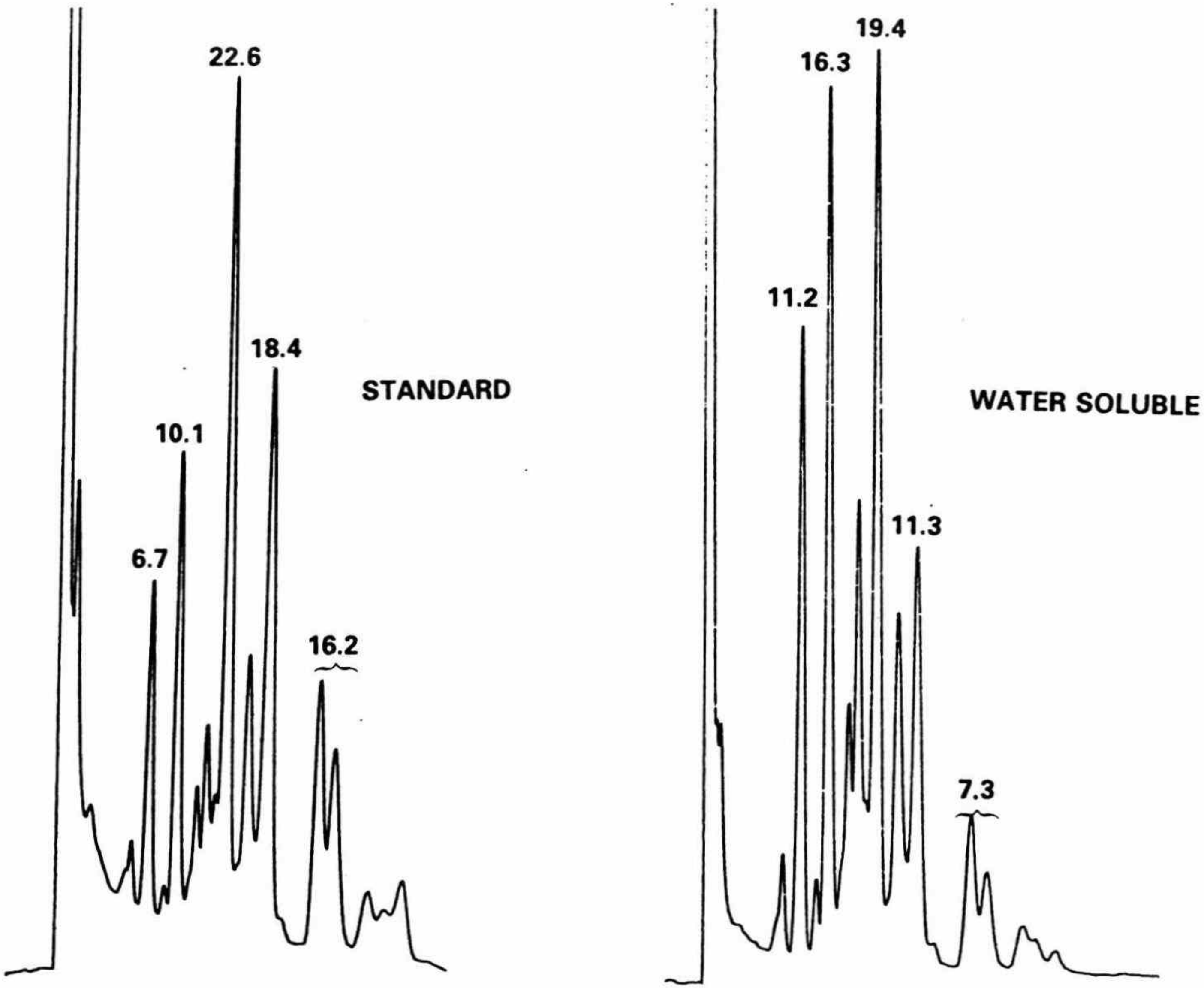
Table IV continued

Compound	Solubility mg/l (ppm)
Pentachlorobiphenyls	
2,2',3,4,5'-	0.022
2,2',4,4',5,5'-	0.031
Hexachlorobiphenyl	
2,2',4,4',5,5'-	0.0088
Octachlorobiphenyl	
2,2',3,3',4,4',5,5'-	0.0088
Octachlorobiphenyl	
2,2',3,3',4,4',5,5'-	0.0070
Decachlorobiphenyl	0.015
4,4'-Dichlorobiphenyl	
+ Tween 80 0.1%	5.9
+ Tween 80 1%	$\gg$10.0
+ Humic acid extract	0.07



James Mieure [7] **Figure** I

AROCLOR 1016



James Mieure 7

Figure 2

APPENDIX I

May 7, 1976

It has been brought to my attention that in two recent and separate incidents, PCB containing capacitors on power poles ruptured without interruption of electrical transmission. Several gallons of PCBs migrated down the poles and soaked into the ground. In one instance one capacitor had ruptured and in the other, two ruptured in the same location. All three units were of the same design, by the same manufacturer and in the same design, by the same manufacturer and in the same series. This represented three failures out of sixty three units installed by one company since January 15, 1976. The utility is in the process of replacing the remaining units while the manufacturer is being contacted to determine the cause of the capacitor failures.

It is requested that the PCB containing transformers and power capacitors in your system be inspected for leakage and that replacement or repair be undertaken as appropriate. Further, it is requested that a report of the finding of your investigation be submitted to me by July 1, 1976. Should leakage be noted, identify the manufacturer, model and series designation so affected. Also indicate amounts of PCBs lost, location and efforts to remove and dispose of spilled and contaminated material.

Your cooperation in this matter of serious environmental concern is appreciated and expected.

Very truly yours,

Eugene F. Seebald, P.E.
Director
Division of Pure Waters

Summary and Conclusions:

PCB containment must be applied not only to manufacturing processes but also to surveillance of past landfills (now containing an estimated 300,000,000 pounds) and also to the seven hundred and fifty million pounds of PCB in sealed units now in use. Disposal of discarded units must be regulated. New chemical type landfills must be provided to contain leachate for complete destruction. Use must be limited to prevent rupture and discharge from units in locations susceptible to such happenings. Adequate substitutes must be developed. Limit of treatment at present is about one part per billion in water discharges.

RELATIONSHIPS BETWEEN THE INDUSTRIAL WASTE MANAGEMENT, THE ENVIRONMENTAL CONTAMINANTS CONTROL ACT AND HAZARDOUS MATERIALS MANAGEMENT

The existence of the Environmental Contaminants Control Act is well known, however, confusion exists over the relationship between the Act and industrial waste management. This confusion is due to a lack of understanding, of the comprehensive nature of the Act and more importantly of those areas to which the Act does not apply. Relationships between waste management and the Act are discussed. Management of Hazardous Materials includes the management of hazardous waste. A total management system for hazardous wastes must address such aspects as identification, classification, transportation, storage, recovery, reuse, treatment and ultimate disposal. Many federal and provincial acts have a bearing on hazardous waste management and even international agreements can influence waste management practices. Two of the international agreements with such an influence are the Ocean Dumping Convention and the Hazardous Polluting Substances Annex being developed under the Great Lakes Water Quality Agreement.

by

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Mr. Monteith, received his B.Sc. in Applied Sciences in 1951 from the University of Glasgow, Scotland. He has had twenty years industrial experience in Canada in the fields of plant management, research development and quality control with chlor-alkali, agricultural chemicals and airline industries. In 1972 he joined Environment Canada where his work has included legislation and regulation development involving hazardous waste disposal.

Relationships Between the Industrial Waste Management,

The Environmental Contaminants Act, and

Hazardous Materials Management

by

J. R. Monteith

Chief, Hazardous Materials Management Division

Environmental Protection Service

Introduction

Most of you are aware that the Environmental Contaminants Act was passed by parliament December 1975 and came into force April 1, 1976. This Act is concerned with environmental chemicals. That is, those chemicals which are in the environment or which have a high probability of entering the environment and which may cause adverse delayed action effects at trace concentrations. Our concern is to apprehend threats to human health or to various sectors of the environment.

All of us in in this country and indeed in the world have a stake in the solutions to this problem. Society desires, needs and uses exotic chemicals in many ways. Industry has developed and is developing new chemicals, in some cases, tailor made for specific applications. In other cases, new uses have been found for existing chemicals. Industry has been concerned with the specific properties of those chemicals which allow them to become a benefit in their industrial and domestic applications. Within the last five, ten or twenty years, society has placed a greater responsibility on industry to determine in addition, the non-beneficial properties and the side effects of these chemicals. Aside from legislation and regulation of the use of chemicals, two forces have come into play which have imposed upon industry an awareness of responsibility to know what they are doing and to be careful. Additionally, in recent times, there is the threat of a retroactive civil damage suit. For example, the Minimata Disease in Japan, mercury in Lake St. Clair and Lake Erie.

Environmental Contaminants Act

The Act contains two main features. The first can be described as investigation. The aim is for a total systematic assessment of a chemical or a group of chemicals regardless of use, media or industrial sector. Industry will be required to report production and other data and to carry out tests. The government will first of all establish some priorities in approach and an identification of problem chemicals. Subsequently, risk decisions would be taken regarding two factors: 1) the likely entry of a chemical into the environment, and 2) whether it constitutes a significant danger to human health and the environment.

The second main feature of the Act deals with control. The Controls are meant to complement existing federal or provincial legislation by defining a residual federal power. The powers are comprehensive, enabling the government to limit or prohibit the release, import, manufacture or incorporation of a chemical in a manufactured product. The Act requires consultation with those federal and provincial regulatory authorities that may have the power to implement some of the desired controls.

Investigation

One aspect of the investigation feature of the Act will be an early warning system, to identify in advance the possibility of a future problem. The difficulty of an early warning system is to ensure that it is reasonably complete and that it works; when one considers the three categories of problems. These categories are:

1) New Chemicals - and the problem they pose because we have no experience with their properties.

2) Existing Chemicals - used for new purposes which may lead to major new releases to the environment in amounts which the environment cannot accommodate.

3) Existing Chemicals about which we suddenly obtain new knowledge about long-term adverse effects such as carcinogenesis.

Each of these categories demands a specific requirement of an early warning system. The first category requires, at the minimum, some kind of pre-market screen and at the maximum, a comprehensive, though realistic testing program for the complete range of acute to chronic toxicities. It can be argued that chronic effects are more important because they are insiduous.

The second category requiring an early warning system is the sudden identification of a new problem with existing chemicals. An example of this would be the intolerable levels of mercury being found in wild fowl in Alberta, or dead fish in some pristine river.

The third category concerns new knowledge about existing chemicals. There are a host of sources of information. There is testing requirements by industry; epidemiology of special groups of the population such as children or chemical workers.

It will be a difficult organizational problem to put together all of these indicators in an inexpensive, yet effective manner. However, the trouble is some substances do have common characteristics:

- they may become widely dispersed in the environment,
- they may be highly persistent and accumulate indefinately in the environment,
- they may accumulate in biological tissues and pass through food chains,

- they may cause biological changes at trace concentrations,
- they may be irretrievable once dispersed in the environment, and
- they may enter the environment in many ways from a large number of sources.

Control

When the Minister of the Environment and the Minister of National Health and Welfare are satisfied that a substance or class of substances will enter the environment and constitute a significant danger in Canada or any geographical area of Canada to human health or to the environment, they shall consult with the government of any province and the departments or agencies of the Government of Canada, to determine whether the significant danger perceived by them will be eliminated by any action taken or proposed to be taken by the agencies under any other law.

After consultation, (or after a consultation offer has not been accepted, the Minister of the Environment and the Minister of National Health and Welfare, if they are still satisfied that the significant danger exists) the substance shall be added to the schedule of the act and controls imposed under regulations which may be made by the Govenor-in-Council. These regulations may control:

1) the maximum quantity or concentration of the scheduled substance that may be released into the environment in the course of any commercial manufacturing or processing activity;

2) the conditions under which the substance may not be released into the environment in the course of any commercial manufacturing or processing activity.

3) The uses of the substances for which they may not be imported, manufactured, processed, offered for sale or used.

4) The maximum quantity or concentration of any scheduled substance that may be contained in any product.

The relationship then to industrial waste disposal would be directly with the controls which are to be put on the release to the environment. An example of this type of control might be in the disposal of PCBs or materials containing PCBs, if this substance was scheduled, and restrictions were put on either the use or disposal of the material. On the other hand, there is a further example, where disposal would not be affected. Let us assume that mercury were placed on the schedule and in this case the sale of Hg thermometers was prohibited. This would mean that any existing regulations on the disposal of mercury in the thermometers would continue and the environmental hazard from the contaminant would be reduced simply by the restriction on the sale, importation or manufacture.

Management of Wastes

It should be noted that the Act is designed to operate as a back-up to other laws, federal and provincial. The control provision is intended to apply only where other authorities fail or neglect to implement appropriate controls. The control of industrial waste disposal therefore by the Contaminants Act would be limited strictly to those items which are scheduled and for which provision is made under the regulations.

The Government intends to emphasize the preventative aspect of the Act. For this to be effective, there is a need to know and to be able to predict what is likely to take place in the future. This means then that the early warning system built into the administration of the act will be the area of greatest emphasis and hopefully will provide controls before the problem exists at the disposal stage. This, of course, is the reason why the Act contains wide powers in the collection of information and requirement for testing.

There are at least forty-seven federal and provincial acts which have some interface on industrial waste disposal. Sometimes, unfortunately, there is in existence an overlapping of jurisdictions with incompatable or conflicting requirements within the Acts, regulations or directions. This is particularly a problem in Canada with three levels of government and a variety of other agencies, such as planning authorities and conservation authorities. Even within any one level of government, many departments and agencies have overlapping interests in the disposal (or reutilization) of waste. Some of the federal legislation which interfaces directly with industrial waste disposal are the Fisheries Act, the Clean Air Act, the Hazardous Products Act, Pest Control Products Act, the Customs Act, and the Explosives Act. Those are simply examples and are not meant to be a definitive list of the federal legislation which could and perhaps should be used before any specific regulations are made under the Environmental Contaminants Act. Similarly, there are a variety of provincial acts. An additional factor is that of international agreements which are developed between nations but which put restrictions or constraints on waste disposal. Two examples of the latter are the international convention on Ocean Dumping which is being implemented now in Canada under the Ocean Dumping Control Act and the annex which is presently under development for the Great Lakes water quality agreement.

Great Lakes Agreement - Hazardous Polluting Substances Annex

The purpose of the Great Lakes annex is to facilitate the development of related programs such as prompt joint spill reporting and response action, compatable regulations and programs for the prevention and control of discharges of the substances listed in the annex from vessels, from shipping activities, from dredged material disposal and from onshore/offshore facilities. The annex will have three appendices.

- Appendix I will be the Hazardous Polluting Substances,
- Appendix II will be a list of substances which have potential as hazardous polluting substances, and
- Appendix III, which is still in the early development stages will designate harmful quantities of the hazardous polluting substances.

For Appendix I, selection of all hazardous substances will be based upon documented toxicological and discharge potential data which have been evaluated by the parties and deemed to be mutually acceptable. Revisions to Appendix I will be as a result of joint action by the parties.

<u>Hazardous Polluting Substances Selection Crtieria - Appendix I</u>

The criteria for determining relative hazards posed by chemicals to the environment fall within three general areas. These are: 1) toxicological; 2) information related to the probability of discharge; and 3) data on the physical and chemical properties of the material which effect its dispersal and persistence in a given body of water. From a toxicological standpoint, an element, compound or mixture, thereafter is considered hazardous, if it poses a threat to one or more of the following areas or aspects of the environment.

1) Toxic effects on aquatic, plant or animal life where the exposure is from immersion.

2) Toxic effects on animal life where the exposure is from dermal contact, inhalation or oral ingestion.

Additional factors which are considered, relate to assessing if there is reasonable chance of the material being discharged. These factors are quantified by knowing the spill history, production quantities, use and distribution patterns, or the extent of other regulation because of special threats to safety, health or welfare.

Appendix II is a list of those substances which have a potential as hazardous polluting substances, but which due to insufficient data, or for any one of a variety of reasons are not presently listed in Appendix I. These substances are given priority attention for examination and possible future inclusion in Appendix I.

Substances are added to Appendix II because they have documented information concerning some of the criteria for schedule I and that some data for other criteria is not available.

Appendix Three, when it is completed, will contain a list of harmful quantities for the substances listed as hazardous polluting substances. At this time, the quantities have not been specified, however, the parties to the agreement will recognize that any quantity of a substance listed in the Appendix I may be harmful.

All of these lists are being worked out with our neighbours to the south, the United States and as such the two parties agree to implement programs in keeping with the requirements of the agreement using appropriate federal, state or provincial legislation.

There is a common bond between this list and the Environmental Contaminants Act in that the substances considered are health or environmental hazards. The Appendix I substances, that is the hazardous polluting substances, will be a list of approximately three hundred materials. These are materials which have sufficient health or environmental hazards along with a potential for discharge, to be mutually agreeable by Canada and the United States as hazardous polluting substances. Some examples of the substances which will likely appear on the list are:

> acrolein, analine, beryllium salts, cadmium salts, chromic salts, pesticides including 2,4-D acid, 2,4-D esters, dalapon, diazanon, dicamba, diquat, lead salts, mercuric salts, phosphorous compounds, polychlorinated biphenyls, tetraethyl lead, zinc and zirconium salts.

An industrial waste which contains any of the materials listed in Appendix I and which is disposed of in such a way that the material will enter the Great Lakes waters will be affected by this international agreement.

Ocean Dumping

A further example of an international agreement which can result in influences in industrial waste disposal is the London Convention or more correctly, the Convention on The Prevention of Marine Pollution by Dumping Wastes and other Matter. This convention was signed by Canada December 1972 and ratified by Canada in November 1975. As a direct result of the signing of the convention, there was a requirement for legislation in Canada to enable this country to live up to the terms of the international agreement. As a result, the Ocean Dumping Control Act was given Royal Assent June 19, 1975 and came into effect December 13, 1975. This Ocean Dumping Control Act requires that no dumping shall take place except in accordance with the terms and conditions of a permit to be issued by Environment Canada. Any such restriction by permit of course must obviously place some pressure on other industrial waste or waste disposal procedures. As part of the Act, there are three schedules.

> Schedule one is a list of prohibited substances including organohalogan compounds, mercury and mercury compounds, cadmium and cadmium compounds. These substances are not normally permitted in Ocean Dumping, however, there are a few very exceptional circumstances under which the dumping may take place.
>
> Schedule two is a listing of restricted substances. These include arsenic and its compounds, lead and its compounds, zinc and its compounds, organosilocon compounds, pesticides and their by-products not otherwise included in Schedule one, beryllium, chromium and nickel. These are substances which require extreme care in disposal in the ocean and are associated with stringent conditions attached to the permit.

Schedule Three is the factors which must be taken into account by the Minister in granting permits for Ocean Dumping. These factors include the characteristics and composition of the substances. The characteristics of the dumping site, and the method of deposit, and in addition there are requirements to consider, effects on amenities, effects on marine life, effects of other uses of the sea, (e.g. impairment of water quality for industrial use) and in addition, but not least, the practical availability of alternative land-based methods of disposal or elimination.

You will note the common bond that exists and that is the consideration of the types of material in the Ocean Dumping, the Great Lakes Agreement, and the Contaminants Act. All of these will, therefore, to some extent, influence industrial waste practices in the future.

Hazardous Waste Management

One division within Environment Canada which has been involved in all of these is the Hazardous Materials Management Division. In addition, we are most actively involved in Hazardous Waste Management. Hazardous waste management means total management from the point of origin within the plant or within the facility to the ulitmate disposal and includes all the steps such as identification, classification, transportation, storage, recovery, re-use, treatment, and finally the ultimate disposal. As has been stated earlier, many federal and provincial Acts have a bearing on Hazardous Waste Management. One of the difficulties of Hazardous Waste Management is the definition of Hazardous Waste. There is no adequate definition except to say that the hazards in a waste disposal system are generally unique to the waste and to the method of disposal as well as the quantities being disposed. The most acceptable definition to date is the one used in the state of Minnesota which reads as follows: "Hazardous Waste means any refuse or discarded material or combination of refuse or discarded materials in solid, semi-solid, liquid or gaseous forms which cannot be handled by routine waste management techniques because they pose a substantial, present, or potential hazard to human health or other living organisms because of their chemical, biological or physical properties." Since there is a proliferation of acts and regulations or potential regulations which may effect hazardous waste management it would seem obvious that there is a need for the various government bodies, the waste generating industry, and the private disposal enterprises to meet to discuss some of the problems involved.

Having said this, the following are a few comments which may be pertinent to such a discussion.

They are some of the discussion points which have arisen from the NATO CCMS Conference on Hazardous Waste Disposal. I think it can be agreed that most if not all apply equally to Canada, particularly in view of the great profusion of legislation and the international pressures as well as the moral pressures which are now being inserted on our society. The comments are:

1) Waste reduction and utilization have priority over waste disposal. Disposal should be chosen only if the first two possibilities do not exist or they are unreasonable. This requirement should be taken into consideration in all government measures.

2) An essential task is the planning of the disposal system. The government authorities cannot escape this responsibilty. It should be carried out in close cooperation and in coordination with the authorities responsible for the disposal of hazardous wastes, the disposal enterprises and the interested groups from industry.

3) The planning of sites for facilities for the disposal of hazardous wastes can only be undertaken on a regional basis. The preparation of individual plans should take account of overall planning requirements.

4) The organization of the disposal of hazardous wastes will be improved by central disposal facilities with a large capacity.

5) The disposal of hazardous wastes in wide areas will be facilitated by the establishment of collection centres.

6) Some of the collection centres should be equipped with facilities for pre-treatment. Transport costs, important in Canada, can be reduced by a reduction in volume or weight at the collection centres.

7) The disposal of hazardous wastes requires controls by government authorities. Controls should extend to the licensing and verification of facilities and to the final disposal of the waste.

8) Among the possible measures for the control of the final disposal of waste, controls at the source should be given priority.

9) The control of transport processes is of special importance.

10) When licenses for waste disposal facilities are granted, the restoration of the utilized terrain should be ensured by the appropriate measures.

11) The disposal of hazardous wastes and the operation of disposal facilities is not in principle the responsibility of the government. The waste generating industry as well as private enterprise have to take over important tasks in this field. Even if waste disposal is organized on a private basis, it may be necessary for government or government controlled facilities to be available.

12) The classification of Hazardous Wastes is of decisive importance for the organization of their disposal as a basis for planning and control.

13) Waste exchanges are an effective organizational means to increase utilization of industrial residues. The establishment, maintenance, and effectiveness should be encouraged by appropriate measures.

14) The financing of facilities for the disposal of special waste constitutes a problem, irrespective of the ownership of these facilities. This problem can be solved by the provision of financing concepts, the financing from a general budgetary fund only appears justified in very exceptional cases.

15) From the point of view of liability and safety, the size of the capital of disposal enterprises is of special importance. These aspects can also be taken into account by imposing the obligation to take out insurance, or by other appropriate measures.

16) The possiblities to grant low interest loans should be exhausted.

17) The prices charged for the disposal of hazardous wastes should be based on the disposal costs. The possibilities to achieve equal price levels should be utilized in order to compensate for site disadvantages.

18) The problems of financing the long-term control of land-fill sites for hazardous wastes are still largely unsolved and should be clarified.

It is our intention to institute such a meeting to begin to plan for orderly management of Hazardous Waste Management in Canada.